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Voyager's Path of Discovery

G-Z: 1985's Prize Comet

Halley's Comet Brightens

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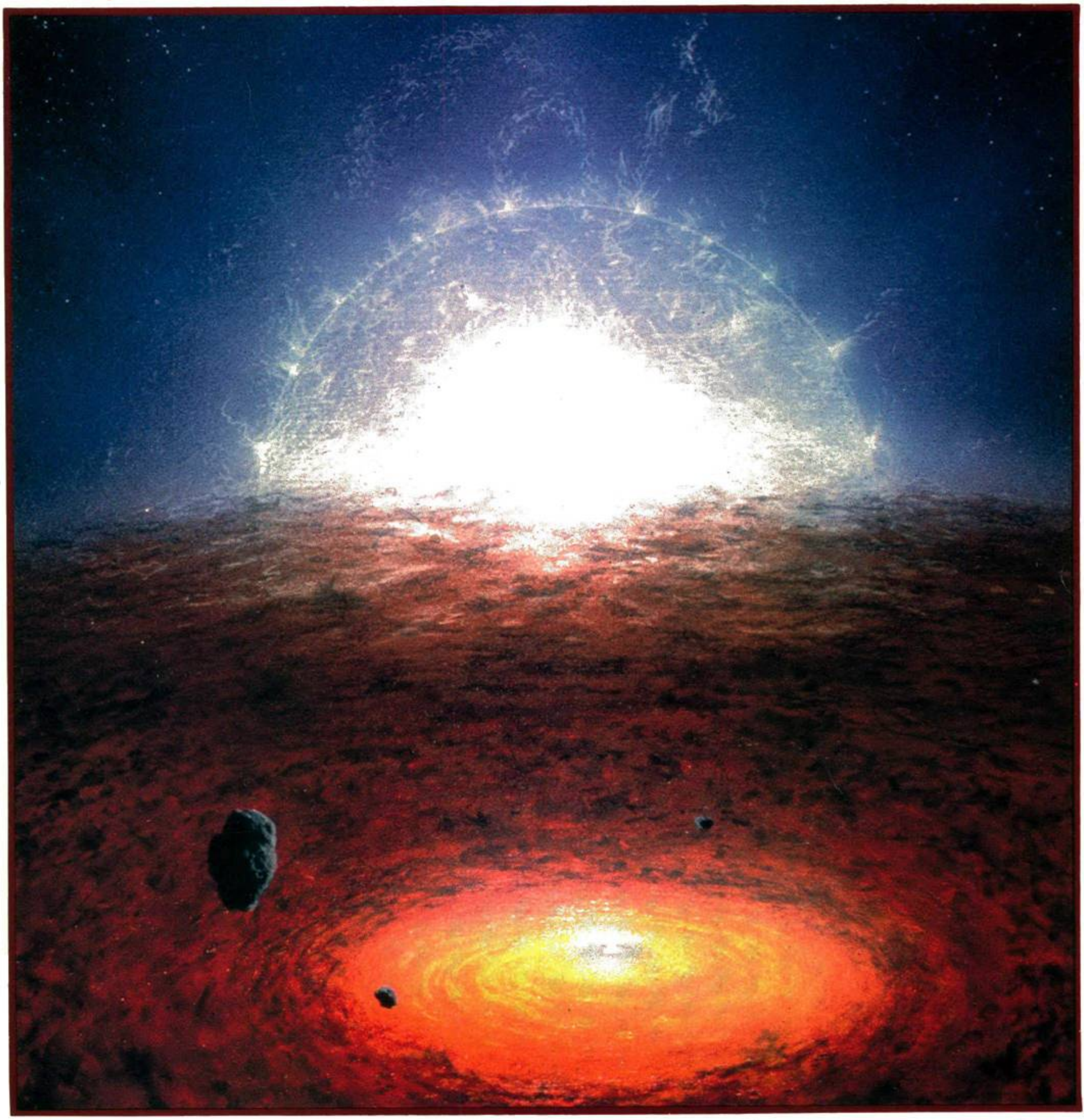

Epsilon Aurigae: Strange Star

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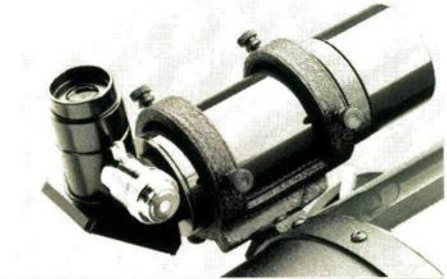

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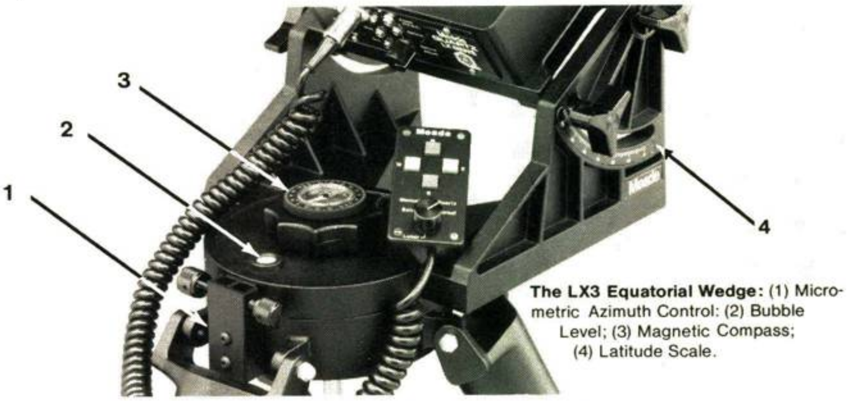

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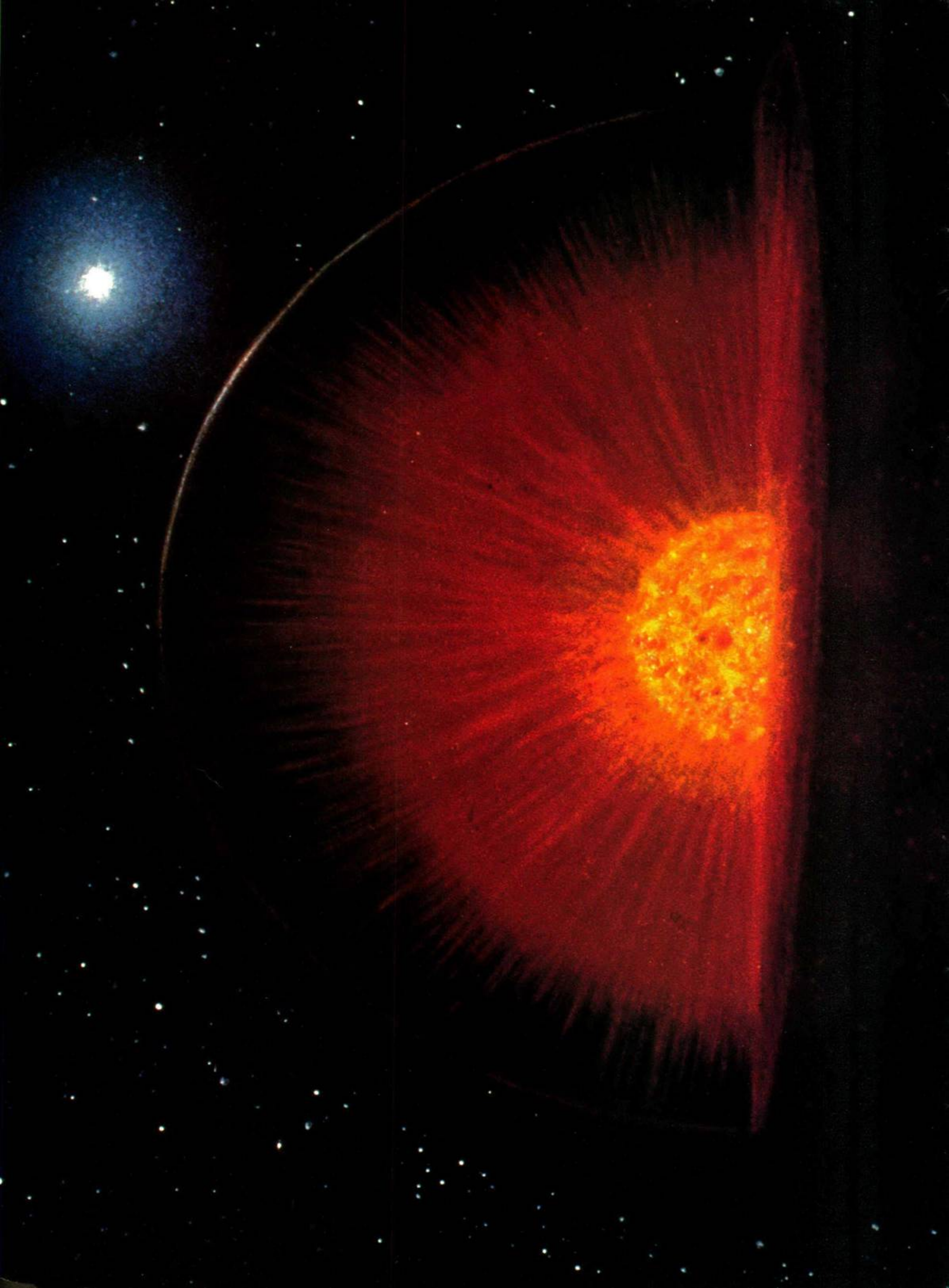

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6 **Epsilon Aurigae**
by Jeffrey L. Hopkins and Robert E. Stencel

12 **Giacobini-Zinner: 1985's Best Comet**

14 **Voyager's Path of Discovery**
by Charles E. Kohlhase

Forum 24 **One Night, Two Men, Three Sites, and 107 Messier Objects**
Clyde Tombaugh is 80: A Look Back at Pluto
Halley: Lost in Perpetual Twilight?
Christmas in August

In Focus 34

Behind the Scenes 35

Photography in Astronomy 38 **Halley Draws Nearer**
by David J. Eicher

Astronomy Reviews 49

Eye on the Sky 54 **Halley Reaches Perihelion**
by Fred Schaaf

Gazer's Gazette 62 **Galactic Clusters for Binoculars**
by James Haas

AstroNews 74

AstroCalendar 80

AstroMart 85

Stellar Frontiers 90 **The Mysterious Cosmic X-Ray Background**
by Barry Parker

Equipment Atlas 100 **A Compact Mount for a Compact Scope**
by Dale Dellutri

The Backyard Astronomer 102 **Carina**

Cover: The star Epsilon in the constellation of Auriga the Charioteer has puzzled astronomers for decades. Many theories and models have been devised to explain this enigmatic star system. The most successful model is perhaps that of Su-Shu Huang who proposed in 1965 that the bright main star has a large disk-like companion. These pages: An earlier model of Epsilon by Margarita Hack called for a secondary star surrounded by a shell of dust. For the latest updates on Epsilon's strange star system, see this month's lead feature on page 6. Paintings by David Egge.

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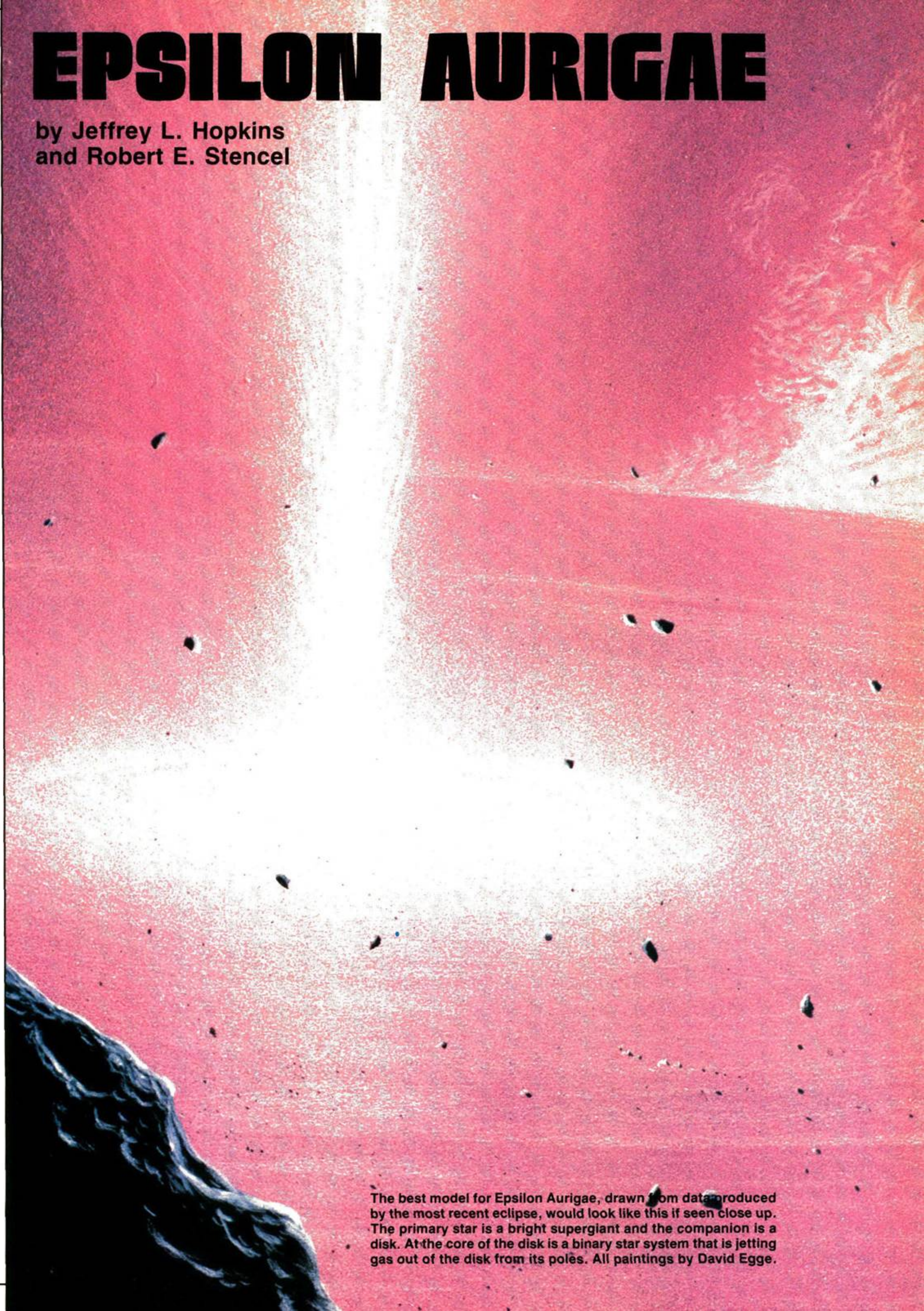
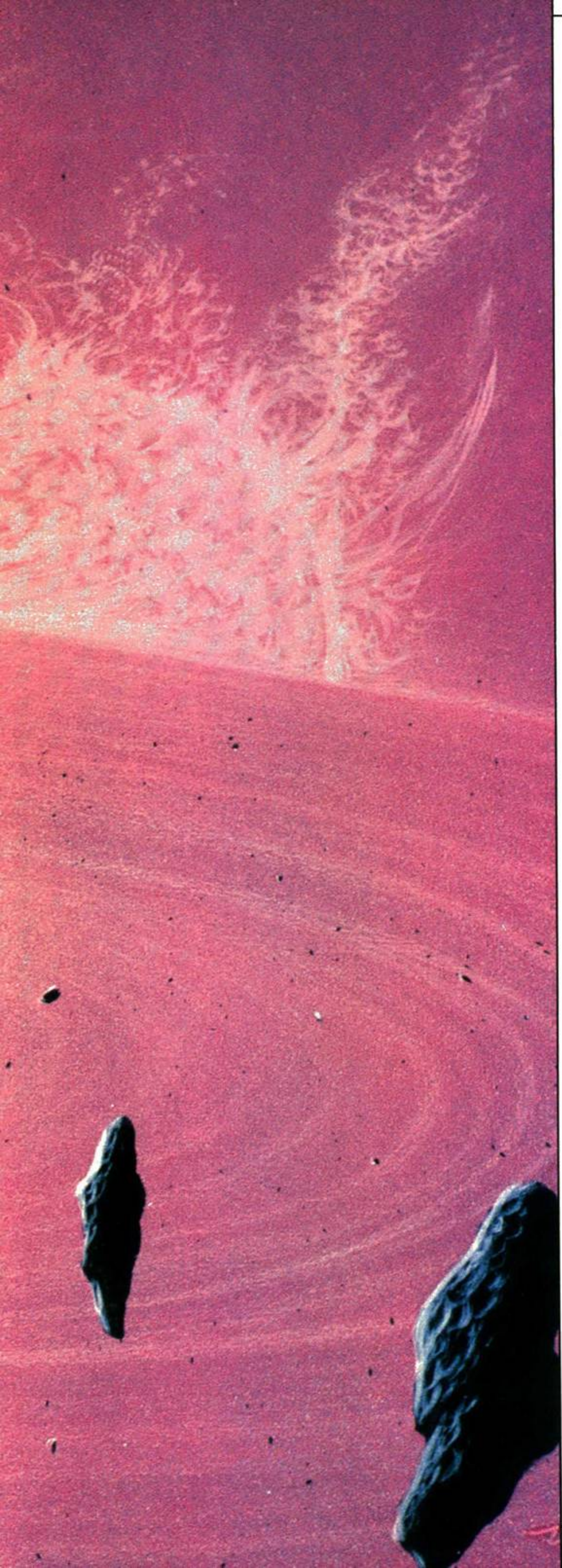
EPSILON AURIGAE

by Jeffrey L. Hopkins
and Robert E. Stencel



The best model for Epsilon Aurigae, drawn from data produced by the most recent eclipse, would look like this if seen close up. The primary star is a bright supergiant and the companion is a disk. At the core of the disk is a binary star system that is jetting gas out of the disk from its poles. All paintings by David Egge.



Astronomy differs from every other science because astronomers are just bystanders to the universe. Unlike physicists, chemists, or entomologists, we can't take things apart or vary one parameter and rerun the experiment. We can only watch and hope that we will be able to learn what is going on from the evidence nature presents. Astronomers are forced to be opportunists on a grand scale — and sometimes the campaigns we pursue don't produce results as clear-cut as we'd like.

Of all the chance opportunities that the universe gives astronomers, few are as fortuitous as eclipsing binary star systems. Simply because Earth lies in the plane created by the orbit of these systems' rotating stars, we are able to see one star eclipse the other. This allows us to deduce the size, shape, mass, and color of these stars.

One such eclipsing binary, however, stubbornly resists our attempts to understand it. For decades Epsilon Aurigae has been studied by astronomers who have, one after another, proposed a succession of theoretical models to explain its mysterious nature, yet no definitive model has emerged. A recently completed worldwide effort by both professional and amateur astronomers has produced new insights, but Epsilon Aurigae remains elusive.

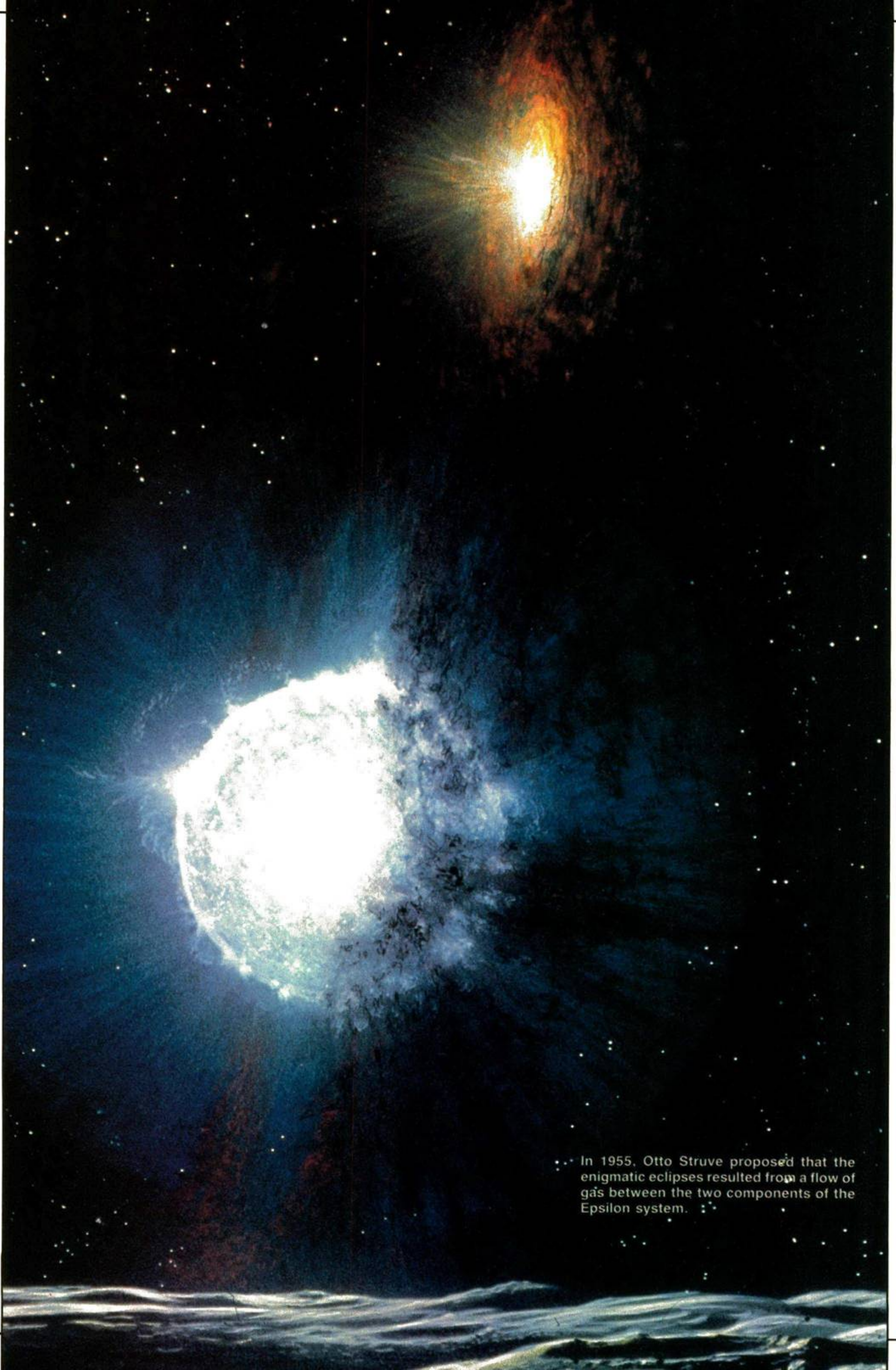
Epsilon Aurigae is a third-magnitude star in Auriga, the constellation of the Charioteer. If tonight is clear, step out into your backyard around 8 p.m. and look high overhead in the north. Auriga is the large pentagon of stars in the crisp, black sky between Orion and Polaris, the North Star. About one finger-width southwest of bright Capella lie three little stars called "the Kids." Of the three, Epsilon (ε) is the one closest to Capella.

Astronomers know Epsilon as an eclipsing binary about 2,000 light-years distant. These double star systems have a bright primary star that is periodically occulted, or eclipsed, by its dimmer companion. The brightness of a typical eclipsing binary remains constant most of the time, but as the dim secondary star eclipses the bright primary it blocks part or all of its light and the apparent brightness drops. After the secondary moves away from the primary's disk, the system reverts to its former brightness. Often there is a second, lesser brightness dip when the companion star orbits behind the primary and *its* light is cut off. Eclipsing binaries differ from true variable stars in that the light variation occurs because Earth happens to lie in or near the plane of the star system's orbit.

This accident of geometry is what makes eclipsing binaries so useful to astronomers. When one star moves in front of another, the change that takes place in their combined light offers many clues about the stars' natures that would otherwise pass undetected. In effect, eclipsing binaries let astronomers probe stellar atmospheres in a way impossible with solitary stars.

As eclipsing binaries go, however, Epsilon is nearly unique. It has a very long orbital period (27.1 years) and, unlike most eclipsing binaries which have two more-or-less ordinary stars, the eclipsing object in the Epsilon Aurigae system seems to be large, massive, and invisible. Unfortunately, Epsilon is so far away that its individual stars cannot be resolved; all we can see is their combined light. And since its orbital period is so long, astronomers have had few opportunities to view its eclipses. Consequently, Epsilon Aurigae and its mysterious secondary have baffled astronomers since the turn of the century.

This much at least is certain: the secondary object — whatever it is — eclipses the hot supergiant primary star for about 700 days every 9,885 days. Astronomers have



In 1955, Otto Struve proposed that the enigmatic eclipses resulted from a flow of gas between the two components of the Epsilon system.

ruled out the possibility that Epsilon's companion is any kind of spherical object like a conventional star. Instead, the factor-of-two (0.8 magnitude) reduction in the system's brightness and the extended flat minimum in the eclipse light curve call for an elongated, opaque object such as a disk seen edge-on. By studying the motions of the binary system and approximating the mass of the primary star (20 solar masses) from its spectral characteristics, astronomers calculate that the secondary has a mass 16 times that of the Sun. The primary and secondary are separated by a distance of 30 astronomical units, or roughly the average distance between Neptune and the Sun.

Epsilon's variability was first noted by the German amateur astronomer J.H. Fritsch in 1824. But it was not until 1904 that H. Ludendorff established the 27.1-year period of the eclipses and their two-year duration. By the late 1930s, knowledge of the system's properties had accumulated and the first attempts emerged to explain its bizarre properties. In 1937, Gerard Kuiper, Otto Struve, and Bengt Stromgren suggested that the companion was very large, semi-transparent, and cool (about 1000 degrees Kelvin). This model stood for about two decades until the middle 1950s when Struve suggested that the eclipses were caused by gas streams flowing between the two stars. In 1961, Margarita Hack proposed a hot star enveloped in a shell as the companion.

In 1965, Su-Shu Huang achieved a major conceptual breakthrough. He suggested that the companion was an opaque disk 40 astronomical units across with a temperature of 500 degrees Kelvin. This basic model is still used today, though it has been revised in several important ways. For example, two years ago Jack Lissauer and Dana Backman of the University of Hawaii proposed that the disk has a pair of stars at its center.

As the 1982-1984 eclipse of Epsilon approached, a joint effort to study the star developed between the American Astronomical Society, the International Amateur-Professional Photoelectric Photometry Association, and the International Astronomical Union. The campaign was similar to that organized for the 1955-1957 eclipse by noted binary star astronomer Frank Bradshaw Wood of the University of Florida. Out of that eclipse campaign came a superb light curve measured for the first time by modern standardized photoelectric means.

This time, however, astronomers had many more tools available to them — a natural outcome of a quarter century's progress in astronomical instruments. The range of wavelengths for observing the star was also much greater: many more optical wavelengths were available as were those in the radio and ultraviolet regions. Astronomers studying Epsilon's eclipse could amass a much fuller observational record than yesteryear's astronomers could have hoped for.

The "1982-1984 Epsilon Aurigae Eclipse Campaign" was officially kicked off at the January 1982 meeting of the American Astronomical Society. This culminated several months of preparatory work and consultations by Douglas Hall of Vanderbilt University, Russell Genet of Fairborn Observatory, and Brad Wood.

In the spring of 1982, a bimonthly newsletter was created to keep observers up to date. We were involved, along with James Kemp of the University of Oregon, in coordinating the incoming reports: Kemp handled the polarimetry results; Hopkins, the photometry; and Stencel (then of the University of Colorado and NASA), the spectroscopy.

The basic principle in the campaign was to give over much of the photometry to amateur observers, thus freeing the professionals to tackle observations (spectroscopy, polarimetry) that they alone had the resources to undertake. In 1955, photoelectric photometry was on the cutting edge of professional research; in 1982, the photometric data came almost wholly from backyard astronomers whose telescopes ranged from a 6-inch to a 20-inch. This reliance on amateurs isn't as strange as it sounds. With Epsilon, a large telescope is more of a handicap than an asset since the star is bright enough to overload the sensitive equipment on large telescopes.

Nearly sixty small backyard observatories around the world pitched in and contributed data on the star system. Besides measurements in the standard UBV system (see box on page 10), some observatories also monitored Epsilon in R and I (red and near infrared) wavelengths as well. In all, nearly 3,000 UBV data points went into the light curve for this eclipse. Since each data point represents close to an hour's work in collecting the data, reducing it, and processing it, this represents a substantial amateur effort, all of it volunteer.

After the campaign, Brad Wood summed things up by saying that without the efforts of the backyard astronomers, "there would have been no [visual] light curve at all for this eclipse."

So what do the results show? The light curves, in their characteristically abstract way, display some interesting features. For one thing, they show that this was not a simple eclipse. As the secondary object began to cover the primary (an instant called first contact), the brightness flickered up and down by about a tenth of a magnitude. This also occurred at fourth contact at the end of the eclipse. (Second and third contact are the "internal" times when maximum eclipse begins and ends.)

The fluctuations probably result from a combination of causes. The ragged outer edge of the occulting disk causes an effect not unlike that produced when a thin sheet of cirrus cloud covers the Sun. But this doesn't explain all of the flickers, part of which must come from changes in the brightness of the primary star itself. Unfortunately, it's extremely difficult to separate the two effects, though further study of the data may disclose a way.

Perhaps the most intriguing feature of the light curve is the 0.2 magnitude brightening that occurred at mid-eclipse. Unfortunately, it took place when Epsilon was near solar conjunction, so only observers located at high northern latitudes were able to observe it. Nevertheless, Stig Ingvarsson of the Tjornisland Astronomical Observatory in Sweden (latitude 58° north) was one of the few who was able to observe this part of the eclipse. With Epsilon Aurigae close to the horizon and near the position of the Sun, taking measurements was difficult.

But despite all the observational difficulties, there's no doubt that the brightening at mid-eclipse was real. It was observed by several astronomers using different techniques and it had been noted during the previous eclipse. But what causes it? Exotic models abound, including one that claims the secondary is focusing light from the primary star by means of a gravitational lens. Another idea is that we are seeing a kind of symbiotic reaction between the two components of the system. The most popular suggestion, however, is that the secondary's disk has a hole or thin spot in the middle. When the thin spot lines up with the primary at mid-eclipse, some extra light leaks through.

The multi-spectral observations also produced an abundance of data, but the details don't make interpreting the Epsilon Aurigae system any easier. Each provides only part of the picture. It's like the old story of the blind men describing an elephant; each observing technique "touches" only part of the star system.

Several major questions emerged from the recent eclipse. If the companion to Epsilon Aurigae is basically a binary star, as Lissauer and Backman suggest, why don't we see many more systems that behave as Epsilon does? Given all the triple star systems in the universe, Epsilon Aurigae should have some cousins.

Second, while embedding a binary star within the secondary's disk is an attractive way to get a large-mass, low-luminosity object — which is what the IUE satellite data show — then why is the exterior of the disk as cold as the IRAS data claim? Disk material ought to be falling onto the surfaces of the binary stars, causing them to heat their surroundings far more than the evidence permits. Perhaps the disk has jets of gas squirting out of its poles, which could carry off heat and cool the disk. When the polar streams of gas crossed the primary star's disk at mid-eclipse, we would see a varying hydrogen absorption, which has also been noted.

With all the efforts of the past three years, are we any closer to knowing what Epsilon Aurigae really is? Unquestionably, yes. But astronomers aren't as far along in their understanding as they'd like to be. The best model of Epsilon Aurigae that emerges from the recent eclipse campaign shows a slightly tilted disk, possibly containing a binary star and polar jets, that has a thin spot in its center. The disk eclipses a slightly-pulsating F-type supergiant with its own tilted ring of hot gas. This much seems fairly well established.

But it would be a mistake to seize upon this as the ultimate model; it's pretty, but too many jigsaw pieces are left over. To take just one example, if the disk is tilted sufficiently to produce the observed ultraviolet polarization changes, then we should be able to see directly into the disk's core and detect radiation from the binary star within — but we don't. Yet if the disk is fat enough to hide the binary pair, then the optical eclipse should be much deeper and the spectral changes much stronger than observed.

If the tentative nature of the "new" Epsilon Aurigae leaves you somewhat frustrated then you're in good company. Astronomers don't like to spend so much effort without feeling they've got the problem largely wrapped up. Science seldom produces tidy answers but, all the same, it's easy to sympathize with the feelings that led astronomer Ed Guinan of Villanova University to say, perhaps sardonically, "I don't think we'll *ever* know how this thing works."

It's important to keep in mind that the complete data set from the recent eclipse has not yet been published, and no one has yet come to grips with the total picture. Odd pieces that don't fit in now may well find their niche when enough theoreticians have thought about them, talked about them, waved enough arms in the air, and finally pushed enough chalk across enough blackboards.

Epsilon Aurigae, at the time of this writing, still presents a challenging problem, perhaps the most intriguing in stellar astrophysics. Careful study of the data from this eclipse will certainly lead to an improved understanding of this mystery star, but a final answer may elude us once again. If this happens, today's younger astronomers can console themselves with the fact that Epsilon Aurigae's *next* eclipse begins in less than a quarter of a century, in the late summer of 2009.

Jeffrey Hopkins is an amateur astronomer actively pursuing photoelectric photometry from his Hopkins Phoenix Observatory in Phoenix, Arizona. Robert Stencel is an astronomer at the Center for Astrophysics and Space Astronomy, University of Colorado, Boulder.

Backyard Photoelectric Photometry

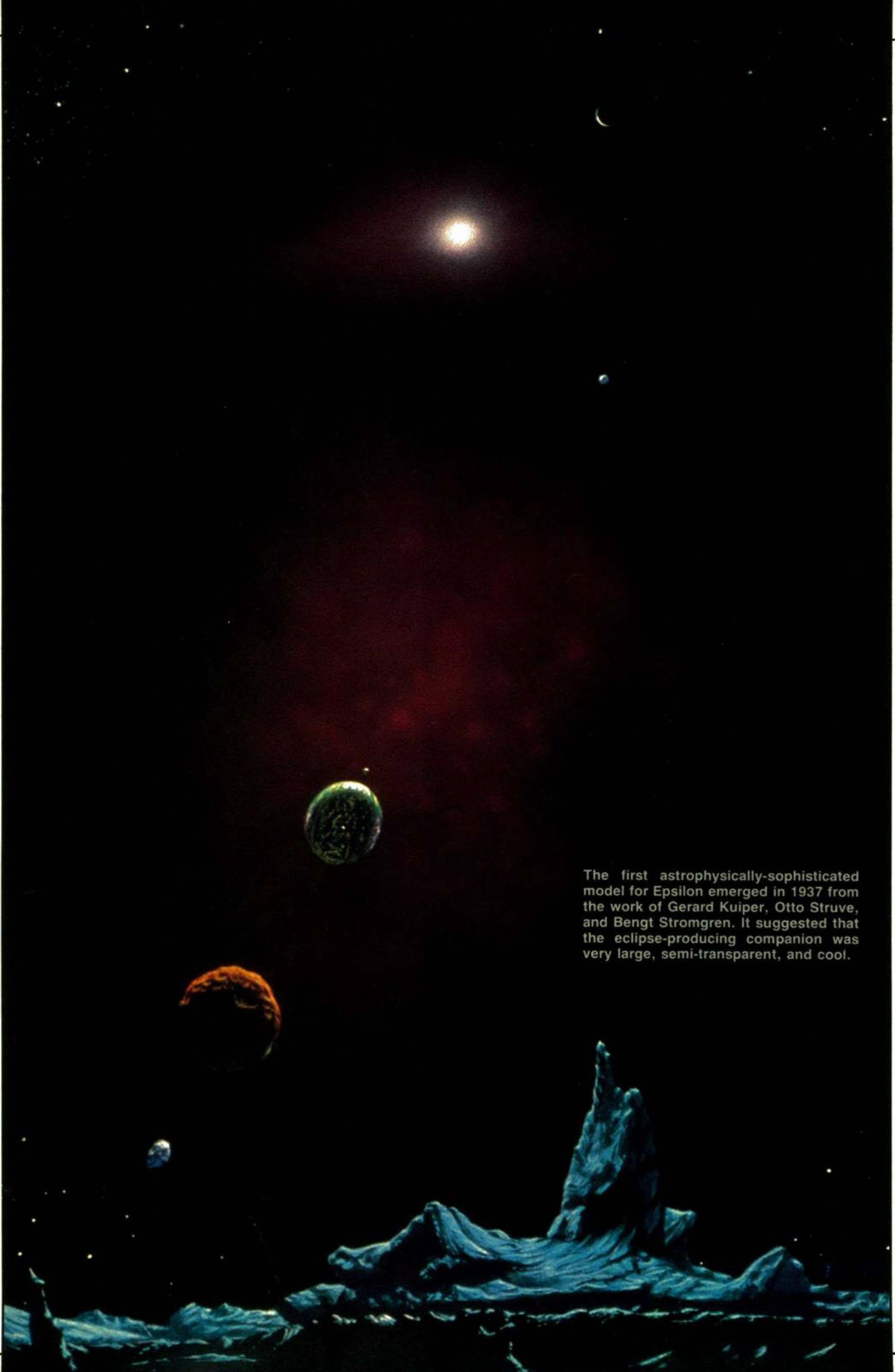
Almost alone among the sciences, astronomy is a field where an amateur can do original work. For astronomers, the "laboratory" is the sky, which is available to anyone who wants to use it. Granted, the larger observatories have very expensive and elaborate equipment but this isn't always necessary for serious research. People have been making astronomical observations for centuries with little or nothing more than the human eye as an instrument. Even today the backyard astronomer with modest equipment who is interested in variable stars can make significant contributions to astronomy.

For many years, backyard astronomers have been making visual estimates of variable star brightnesses by comparing them to nearby stars of known magnitude. Since 1911, the American Association of Variable Star Observers has coordinated these activities. But visual estimates are accurate to only about a tenth of a magnitude at best. Recently, a few backyard astronomers have adopted a much more accurate method — photoelectric photometry — that permits measurements to an accuracy of 0.01 magnitude or better. (See "Backyard Photoelectric Photometry," ASTRONOMY, February 1983.)

Photoelectric photometry is, basically, a brightness-measuring technique that uses a very sensitive light detector attached to a telescope. The method is simple in principle, if a little involved. First, you center the star of interest in the photometer's eyepiece. Next, isolate the star in the field with a diaphragm so that only the star and a very small area of sky around it is visible. Flipping the view mirror out of the way allows the starlight to reach the sensitive detector (a photomultiplier tube or solid-state photodiode). The light generates a small current in the detector that is measured and recorded. The brighter the star, the larger the current. To check your readings, measure a tiny region of blank sky and two other nearby stars that are known to be constant in magnitude using this same sequence of operations.

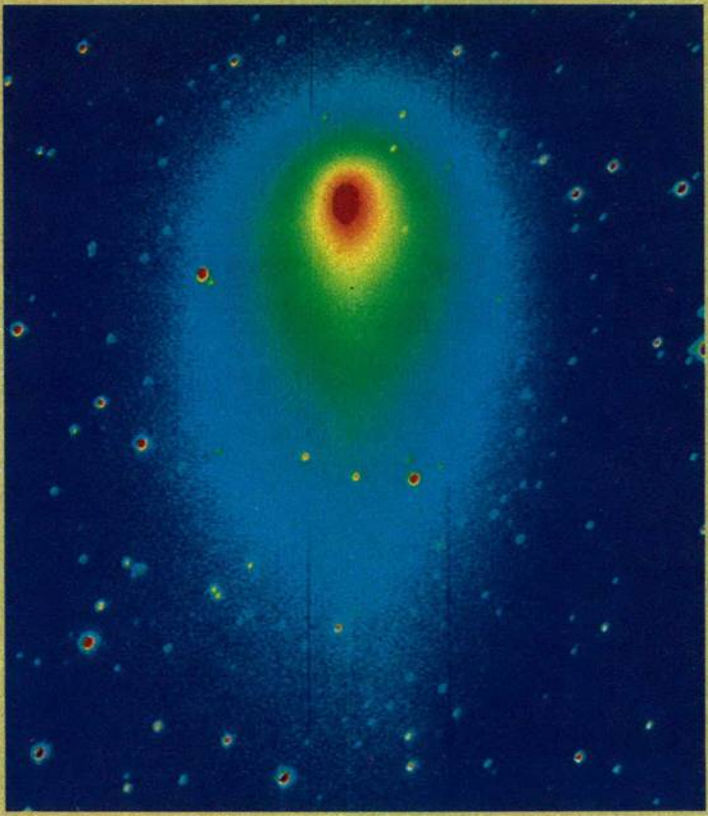
Because stars have different brightnesses at different wavelengths, or "bandpasses," astronomers send the starlight through special standardized color filters before it reaches the detector. Depending on the star, its color, and the specific filters used, an astronomer can often tell a lot about physical conditions in the star by the way its brightness differs from one color to the next. The most common standard filters used by backyard photometrists are those of the UBV system. The letters stand for ultraviolet, blue, and visual (the last is similar to what the human eye sees). Quite often with eclipsing binaries, the changes in the visual bandpass are hardly detectable, whereas the ultraviolet can show very pronounced changes.

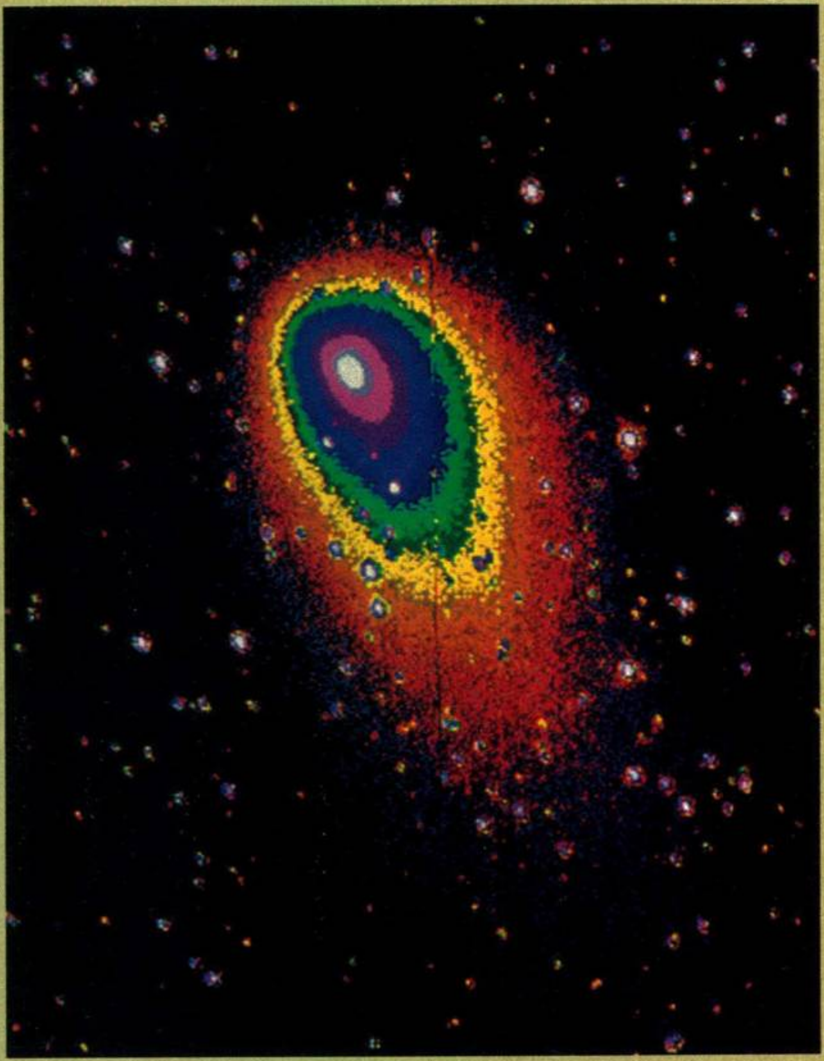
With today's simple and sensitive photometer systems small telescopes can give excellent photometric results, and they are relatively easy to use. Amateur astronomers, therefore, can contribute to our understanding of the universe right from their own backyards. In fact, several papers have been published in professional astronomical journals with data submitted by enterprising amateurs.



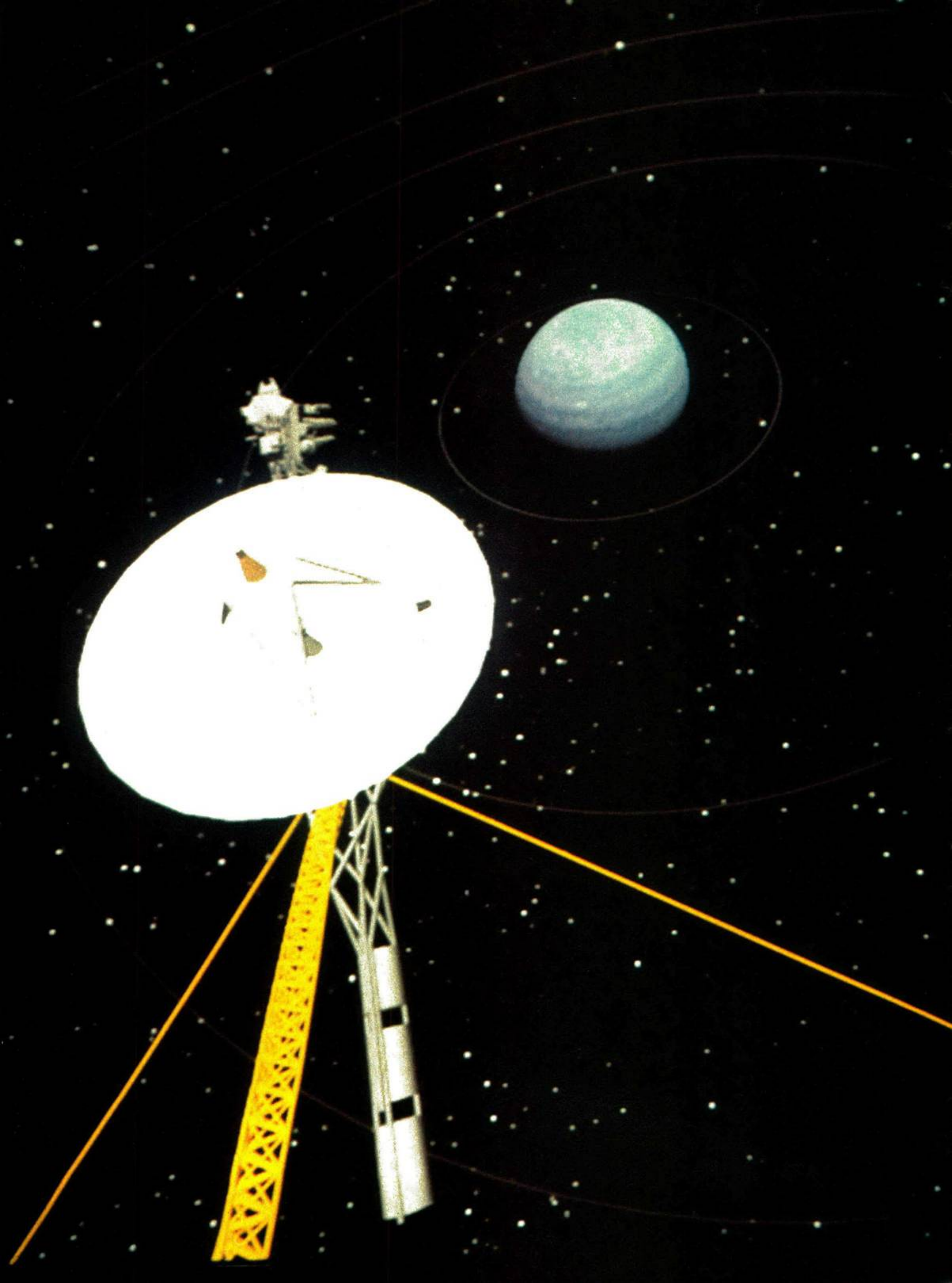
The first astrophysically-sophisticated model for Epsilon emerged in 1937 from the work of Gerard Kuiper, Otto Struve, and Bengt Stromgren. It suggested that the eclipse-producing companion was very large, semi-transparent, and cool.

Giacobini-Zinner: 1985's Best Comet





During the summer and fall of 1985, Comet Giacobini-Zinner (G-Z), a periodic comet that returns every 6.5 years, stole the show from Comet Halley. It brightened to nearly 7th magnitude, becoming visible in binoculars and backyard telescopes everywhere. The International Cometary Explorer spacecraft passed through G-Z's tail last September, transmitting data on the comet's composition. Opposite page: G-Z on August 22nd, when it was near the height of its brightness. Top: The same photo processed to show isophotal contours of increasing brightness. Above: G-Z after perihelion on October 19th. Left: This photo of G-Z on July 19th shows the extensive dusty coma (red). All photos by Uwe Fink, Al Schultz, and Mike Di Santi, who used the 61-inch telescope and a CCD camera at the University of Arizona's Catalina Station.



Voyager's Path of Discovery

by Charles E. Kohlhase

As you read this, Voyager 2 is exploring a vast uncharted wilderness. . .

Imagine that you are making the very first trip to a remote area of Earth that has never been explored. It's your assignment to report on what you find there. Consider the requirements of the job before you: You will need a means of transportation, a map of the area, certain navigational skills to avoid losing your way, plenty of supplies, a camera (plus a thermometer, barometer, and hygrometer if you want to report on the local weather), a means for handling emergencies on your own, and finally a way to "call home" if you have some hot news or if you find yourself in deep trouble.

Your imaginary mission of discovery requires the same capabilities as the real mission of Voyager 2. When Voyager reaches Uranus on January 24, it will be relying on five basic elements. These include the *spacecraft* (that's you), which is capable of carrying a variety of sensors to the destination in order to conduct the *science* (your pictures and measurements) that you have in mind. The spacecraft cannot escape from Earth's gravity without the help of a *launch vehicle* (for you, say, a canoe). In the olden days of space travel, this would have been an expendable set of rocket stages, but now we reach Earth orbit with the reusable Space Transportation System, or Space Shuttle, and we go into interplanetary space with a high-energy upper stage rocket.

No launch vehicle or spacecraft has an error-free guidance system so you'll need some sort of *navigation* system to reach your destination. Voyager uses huge tracking antennas for radio ranging and making measurements of its signals' Doppler shift to estimate the spacecraft's location to within several hundred miles. As it nears the destination, the spacecraft takes pictures of satellites against the star background to improve its position estimate to within less than one hundred miles. If the spacecraft's flight path is off course, mission controllers send commands that fire small thrusters to correct its course.

As a human explorer, you have to make your own decisions. But as you can imagine, Voyager 2 needs a lot of *support* from Earth base — a vast complex of people, computers, communication lines, and special equipment.

As Voyager cruises happily along, locked onto the Sun and a guide star using onboard fault protection logic to react to problems, it still needs instructions from Earth. First, a group of scientists selects the observations they want Voyager to make. Next, flight team personnel at the Jet Propulsion Laboratory (JPL) in Pasadena — experts in such areas as mission planning, spacecraft engineering, flight operations, and sequence implementation — schedule and design the observations into a "master activity timeline." Computer programs at JPL are then run to produce the instructions to be radioed to Voyager. Finally, each of these "sequence loads" is uplinked from one of the large tracking antennas of the NASA Deep Space Network. Following its list of instructions of what to do and when to do it, Voyager aims its sophisticated sensors at the remote worlds it visits and records the images, temperatures and other properties it finds.

Unlike a human explorer, the spacecraft is making a one-way journey. Since it will never return, Voyager carries communications gear to transmit back its findings about the strange makeup of the giant outer planets and their retinue of moons, rings, and surrounding particles and fields.

Three hours before closest encounter, Voyager speeds toward the Uranian system. Circles represent the orbits of Uranus' satellites (from center): Miranda, Ariel, Umbriel, Titania, and Oberon. The camera platform is behind the spacecraft in this view; the antenna points back toward Earth. Computer generated images in this article courtesy of JPL/NASA.

Spacecraft Health

Voyager 2 has been performing like a champ for over eight years. Although "aging at about the same rate as dogs and horses" — a metaphor coined by Dr. William McLaughlin, manager of the Flight Engineering Office at JPL — the spacecraft has experienced only two major problems.

The first of these occurred in April 1978 when Voyager lost one of its two radio receivers and a tracking loop capacitor in the surviving receiver. As a result, commands from the ground controllers can now only be accepted if the transmitted frequency is within ± 96 cycles per second of the receiver's "rest" frequency, which unfortunately changes with the rest frequency of the receiver. A temperature shift in the receiver compartment of only ±0.5°F is sufficient to cause Voyager to turn a deaf ear on instructions from Earth unless Earth compensates. To do this, the engineers have planned the Uranus encounter sequences to include a liberal number of thermally quiet periods for transmitting instructions to the distant robot.

The second major problem occurred when the scan platform — which carries the cameras, infrared sensors, photopolarimeter, and ultraviolet spectrometer — stopped moving about its azimuth axis 1½ hours after closest approach to Saturn in August 1981. After a frantic week of worry, spacecraft engineers got the platform unstuck. Now, following a long period of studying the problem and testing platform drive actuators in ground laboratories, Voyager's operators believe that a future seizure of the small actuator gear chain can be prevented if they avoid using high-speed slewing rates.

To handle any future problems, spacecraft engineers have devised a way to monitor actuator health. By reprogramming the length of the current pulse through the drive motor electrical coils, they can measure the amount of friction in the gear chain. Should the friction begin to increase, they may be able to reduce it by temperature cycling and rest.

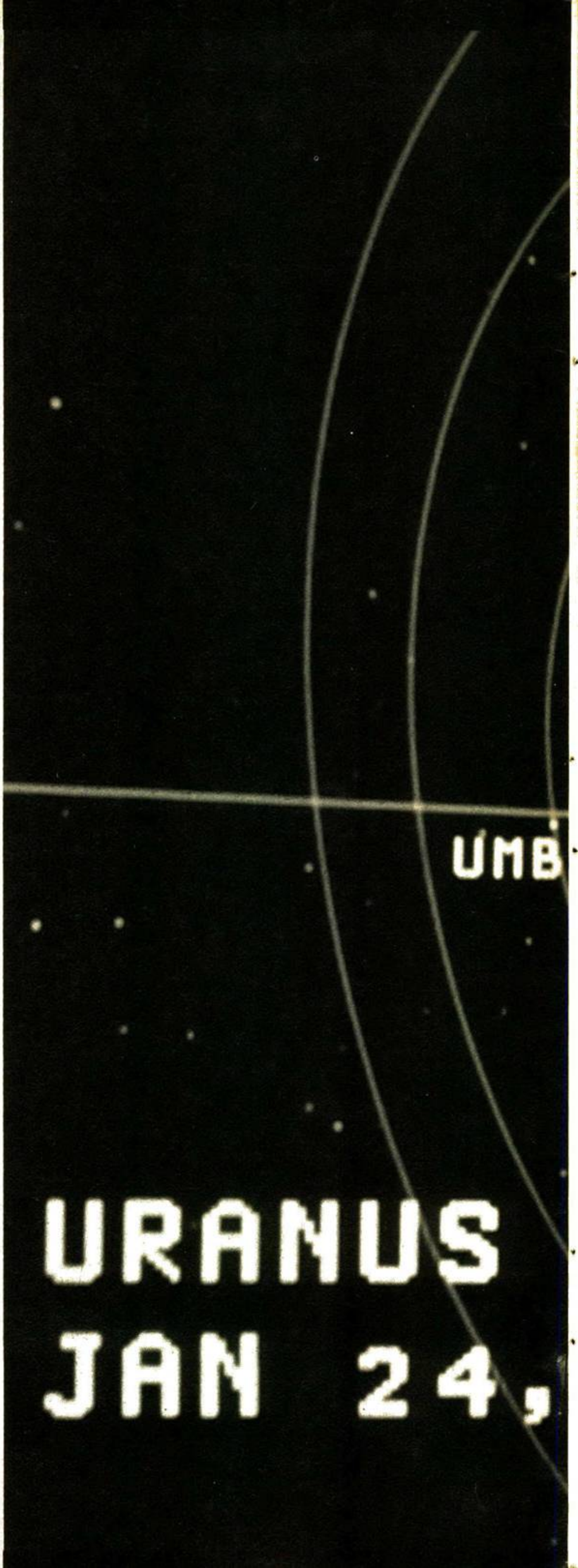
For the few hours when Voyager is deep within the Uranus system and the angular separation of targets is large, the scan platform speed restriction will make it difficult to fit in all of the scan platform activities desired. For this reason, a few medium-rate platform slews have been allowed for faster acquisition of high-priority targets. If the platform shows signs of ill health despite efforts to reduce friction, the engineers will transmit backup sequences to Voyager to substitute spacecraft roll maneuvers for slewing about the azimuth axis.

But enough talk about problems. The Voyager robot is a truly amazing machine comprised of some five million electronic parts. Its high-resolution television camera can read a newspaper headline at a distance of half a mile. Its attitude control gas jets can point the spacecraft and hold it over 20 times steadier than the hour hand on a clock. It has six onboard computers, two of which use fault detection and reaction logic to deal quickly with unexpected problems.

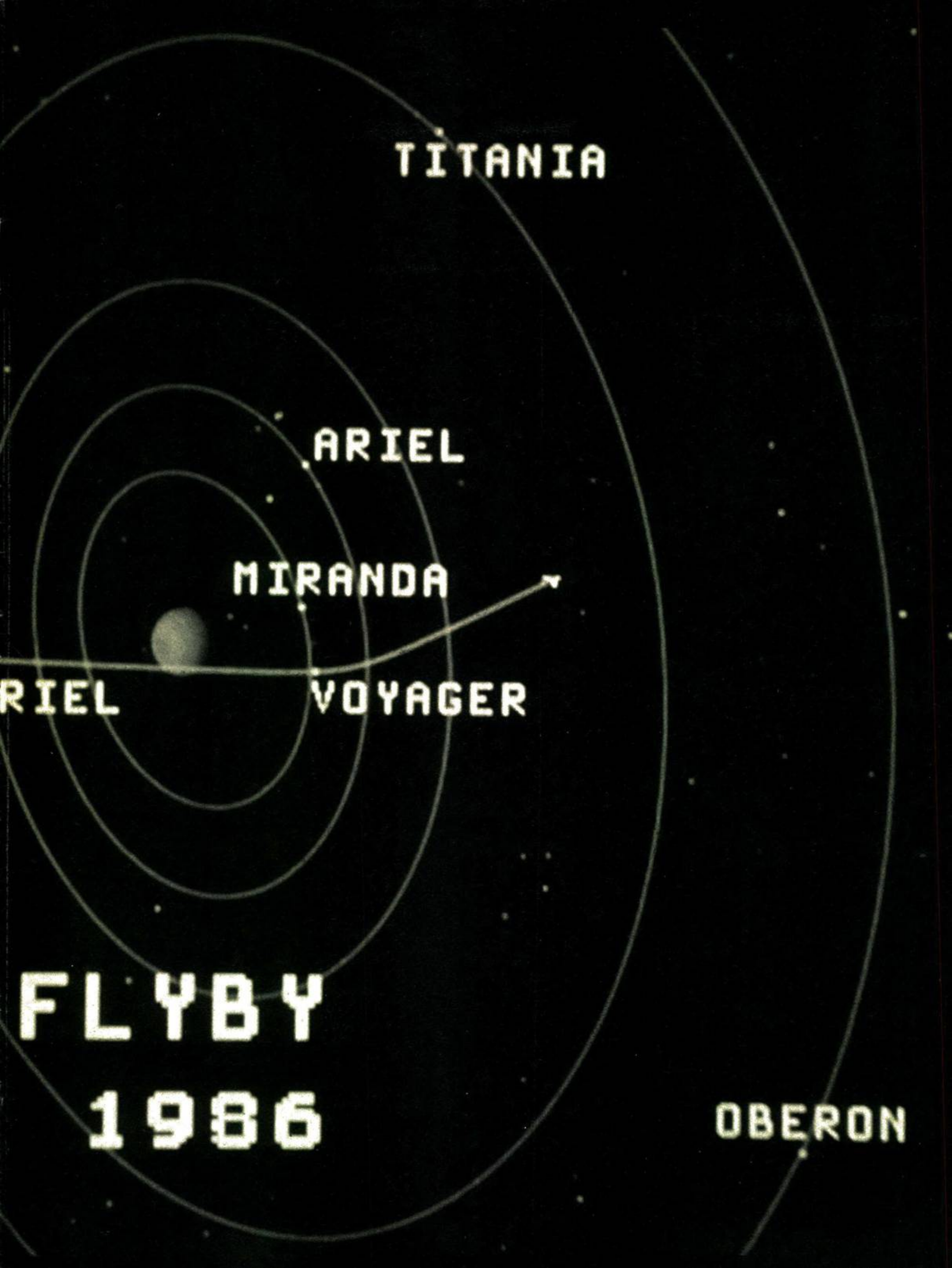
Voyager uses nuclear power sources to generate 7,000 watts of heat, which is converted into 400 watts of electricity to run the robot's many subsystems. Before leaving Earth, its propellant tank was filled with 230 pounds of liquid hydrazine. This propellant fuels the small thrusters that maintain Voyager's attitude in space and correct its flight path when necessary.

To date, Voyager 2 has flawlessly executed thousands of instructions and returned several trillion bits of scientific information. The spacecraft's communications systems, however, were designed primarily for missions to Jupiter and Saturn. Traveling to Uranus, which is twice as far from the Sun as Saturn, has stretched the capabilities of these systems as well as the ingenuity of Voyager's engineers.

In the business of deep space exploration, mission designers must always combat the "square of distance" penalty. As the Earth-to-spacecraft distance doubles, the rate at which Voyager can transmit data back to Earth is reduced. If it takes four times as long to send a picture back to Earth, we can take only one fourth as many pictures! To avoid a severe loss of information, we must either increase the data transmission rate, decrease the number of information bits that comprise each picture, or both. The first has been achieved by adding the signals from more Earth-based antennas, including the Australian Parkes radio telescope, so we can capture the feeble radio signal better and allow faster data transmission. Voyager transmits 22 watts of signal power, but only one billionth



Because Uranus is nearly pole-on to the Sun, Voyager passes through its system of rings and satellites very rapidly. All of the closest approaches occur in a six-hour period. Uranus' gravity deflects Voyager's trajectory and sends it on to its next encounter with Neptune. JPL/NASA image.


TITANIA
ARIEL
MIRANDA
RIEL
VOYAGER
FLYBY
1986
OBERON

of one millionth of one watt ultimately reaches the tracking antennas on Earth.

Reducing the number of bits in a picture is tough, but it can be done. Each Voyager television image is composed of 800 lines and 800 dots per line. Using 8 binary bits (256 shades of gray) per pixel (a "dot" or picture element) results in a total of just over 5 million bits of data for each picture. In a typical space scene, however, much of the picture may be dark space or low-contrast cloud features. Voyager's engineers have reprogrammed one of the onboard computers to "compress" each picture by returning only the changes from pixel to pixel, rather than the full 8 bits of gray level information, thereby reducing the total data needed for each picture to "only" 2 million bits. The net result is that Voyager is able to return a dozen pictures per hour from Uranus.

As the Sun-to-spacecraft distance doubles, the intensity of sunlight is also reduced by four times. Light levels at Uranus are 360 times dimmer than those at Earth. When Voyager views Neptune in August 1989, the light levels will be 900 times fainter than those at Earth. These dim levels, comparable to late dusk on Earth, require camera exposure times of several seconds. If either the camera or the target moves, the picture gets blurred.

Mission planners and spacecraft engineers have tackled this problem and found ways to return sharper pictures. When the movement of a target relative to the spacecraft is too fast, a technique known as "image motion compensation" will be used. Voyager's precision gyroscopes will smoothly rotate the spacecraft to track the target during the exposure. This technique will be used several times during the near-encounter period with top priority on getting sharp, close-range pictures of Miranda, one of Uranus' five moons.

Even when the target is relatively still, Voyager's own shakes and shudders sometimes cause picture blurring, which is aggravated if the onboard tape recorder starts or stops during an exposure. These disturbances have been reduced by special operation of the tiny attitude control thrusters.

Getting Ready for Uranus

Intellectually, we have been preparing for Voyager's encounter with Uranus for more than two centuries, ever since the planet's discovery by William Herschel in 1781. In practical terms, the real work got under way in 1918 when Soviet academician Yu. V. Kondratyuk claimed to have first applied the concept of gravity assist to space flight. The idea itself is simple: By swinging around the trailing side of a planet, a spacecraft can gain speed relative to the Sun and then head out for the next planet.

Gravity-assist trajectories allow spacecraft to go farther and faster than they could otherwise and make large changes in speed and direction. Without Jupiter to swing Voyager on to Saturn, there might not have been a mission to Saturn; without Saturn to provide the necessary boost toward Uranus, the current flyby mission would still be a distant dream.

Another half-century would pass before two JPL trajectory design engineers, Michael Minovich and Gary Flandro, worked out the 1977 Grand Tour launch opportunity, a rare alignment of the outer planets that *would* not recur until the middle of the twenty-second century. This opportunity allowed NASA to send a single spacecraft to the outer planets many years sooner than might otherwise have been possible.

The 1977 opportunity consisted of some ten thousand different Earth-Jupiter-Saturn flight path options; these were carefully pared down to a few nuggets by Paul Penzo, Joe Beerer, Andy Collins, Ed Stone, and myself. But even as we planned for two planets, we made sure that the Voyager 2 spacecraft would be able to continue on to Uranus and Neptune, providing Voyager achieved its high priority Saturn objectives.

Voyager 1 and 2 were launched on schedule late in the summer of 1977, and they have already made history. As distant extensions of human sensory organs, these spacecraft have exposed the secrets of some three dozen worlds. Like tourists in a remote land, they have snapped pictures that reveal Saturn's dazzling necklace of ten thousand strands; the erupting volcanoes of golden Io; the colorful and dynamic atmosphere of gargantuan Jupiter and its centuries-old Great Red Spot; the smooth water-ice surface of Europa that may hide an ocean; the strange world of Titan with its dense atmosphere and variety of hydrocarbons that slowly fall upon strange seas of ethane and methane; the small moon Mimas that was nearly destroyed by an ancient collision; and many other wonders that have expanded the dimensions of our knowledge.

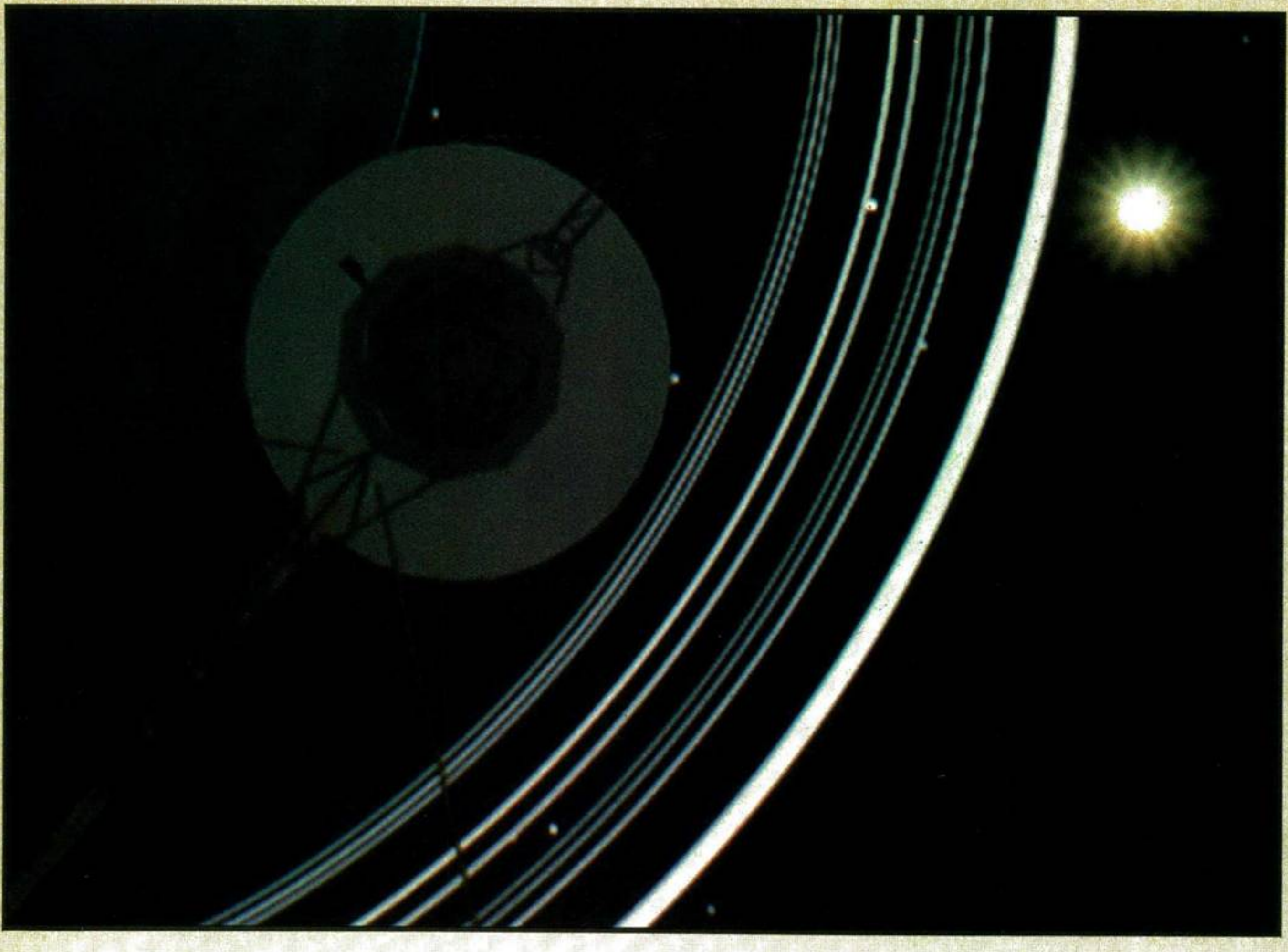
With this record to build on, Voyager dreamsmiths are excited about the excellent prospects of unveiling new mysteries from the realms of Uranus and Neptune. The dawning glows of anticipation were evident at the Science Steering Group meeting held at JPL in the summer of 1984. Serious planning for the encounter began at that time and steadily intensified in the months that followed.

As late as the spring of 1985, project personnel hotly debated the key issues. The Imaging Team lobbied for having the sequence of Miranda pictures continue until the time of closest approach to the satellite, when the lighting angles would be best for seeing surface relief. The Radio Science Team objected, however, because image motion compensation would interrupt their tracking data, thereby reducing the ability to measure Miranda's mass — an all-important element in density and composition models. Project Scientist Ed Stone mediated a compromise: The picture sequence was stopped farther from Miranda but not as far as desired by the mass sleuths of the Radio Science team.

Debates also raged over the demanding ground-support activities required during the final week before Uranus' closest approach. In order to keep the pointing instructions for the scan platform as up-to-date as possible, it would be necessary to successfully execute many computer runs and human decisions in a matter of hours. All hands agreed that the scientific rewards justified these extraordinary efforts for vital late-sequence updates, particularly since a second visit to Uranus is not expected until well into the next century.

Scientists and engineers love to debate issues rich in technical tradeoffs. "If we do A, then B will improve, but C will degrade." These intellectual gymnastics are fun and necessary, but the hard work comes in producing each of the Voyager instructional sequences in the form of flawless computer loads.

Mission guidelines ("Never move the scan platform at high rate," "Use only so much propellant") and science objectives ("Take sharp pictures of Miranda," "Do a radio occultation experiment") are first merged to assemble an overall plan that defines what to do when. This initial activity timeline, as it's called, is then reviewed and refined by the project's engineers and scientists, approved by



Voyager flies behind the rings of Uranus 4.7 hours after the time of closest approach. In this Sun-facing view, we see the shadowed side of both Uranus and Voyager. Radio signals, sent at two different frequencies, will be attenuated by the ring material differently, enabling planetary scientists to learn something about the number and size of particles in the rings. JPL/NASA image.

project management, converted by the Sequence Team into the bit patterns that Voyager understands, and placed "on the shelf" until the date when it must be radioed up to the spacecraft.

The total Uranus observation period from November 4, 1985 to February 25, 1986 will be controlled, or "sequenced," with nine computer loads, each consisting of about 2,500 18-bit words. Each load controls the spacecraft for as long as a month or as little as two days, depending on how close Voyager is to Uranus and how much it must do. Development of the nine sequence loads involved the efforts of some two dozen people over a period of 18 months.

The Uranus encounter is filled with a battery of observations designed to measure a broad spectrum of the planet's properties. Uranus will be scanned, listened to, and sensed from all angles. As Voyager closes in on Uranus, it will approach the planet pole-on due to the planet's unique tilt; Uranus will resemble the bull's-eye of a target with the planet's rings forming the rings of the target. This head-on approach leads to a major problem: All of the closest satellite approaches occur in a single six-hour period. When Voyager passed Jupiter and Saturn, it took 35 hours to fly across the satellite orbits. At Uranus, everything happens at once.

Furthermore, Uranus' own necklace of dark rings may be difficult to photograph clearly until Voyager has passed to the night side of the planet and can look back to watch the particles gleam in forward-scattered sunlight. This effect is well known to Earth-bound photographers seeking a halo-like glow of hair radiance from back-lit subjects.

But pictures aren't everything. From a scientific point of view, Voyager may learn more about Uranus' ring structure using a photopolarimeter to perform three star occultation experiments than it will with its television camera. The most important of these occurs 13 to 9 hours before closest approach when the star Sigma Sagittarii makes a grazing pass behind the rings. By counting the photons of light from the star as it passes behind the rings — the starlight flickering on and off with each gaplet and ringlet — Voyager will acquire a precise profile of the rings.

In doing so, Voyager will be trying to learn many facts about these dark rings. Do they have sharp boundaries, density waves, or spokes? Do small moonlets orbit near ring boundaries to maintain the narrow, eccentric, and slightly inclined rings? What are the ring particle sizes and why are they so dark, unlike the bright, icy rings of Saturn? Were they formed from dark material or might they have become dark after eons of ultraviolet radiation or particle bombardment of methane ice on their surfaces? Voyager

Overleaf: At the moment of Voyager's closest approach, the great blue-green globe of Uranus, girdled by nine slender rings, shines in the dulled light of a distant Sun. JPL/NASA image.

will also be searching for any previously undiscovered rings, presumably near the nine that are presently known.

Of Uranus itself, we will learn plenty. Voyager will scan the green-blue atmosphere to measure its composition, temperature, cloud motions, aurora, and overall planetary energy balance. What is the meteorology of a tilted giant that receives sunlight at the pole rather than at the equator? And why does the internal heat source of Uranus appear to be so much less than that of its near-twin Neptune?

What of the five moons of Uranus? They are not as shiny as Saturn's moons. Is some dark material mixed with their surface water ice? Are they cratered? Are there signs of surface erosion? Voyager will use image motion compensation to obtain the finest possible imaging resolution of Miranda, typically better than one mile. We can measure the size of the moons accurately, but their masses will be difficult to determine because Voyager does not pass close to them. Only Miranda, from a range of 18,000 miles, can be weighed. From its diameter and mass we can estimate Miranda's density, and planetary astronomers can then model possible internal compositions for this tiny, distant world.

While scanning the space around Uranus for undiscovered moons, Voyager will also, at times, search for material ahead of and behind the known moons. A similar search revealed tiny moonlets in the orbital paths of Dione and Tethys at Saturn. Finally, Voyager will measure the strength of the Uranian magnetic field, if it has one, watching for the plethora of strange effects that often accompany the far-reaching interaction between trapped particles and the planet's atmosphere, rings, and moons.

Beyond Uranus

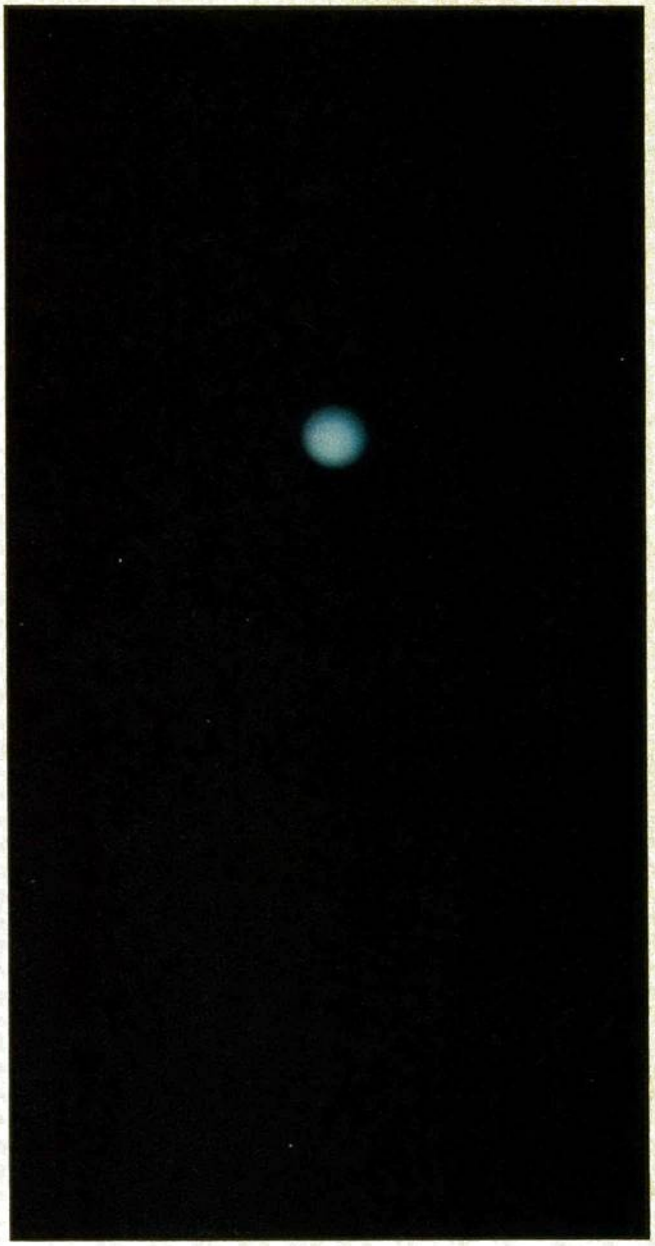
Voyager 2 will use the gravity-assist flight corridor at Uranus to gain the necessary speed for its journey to Neptune. Arriving on August 24, 1989, twelve long years after its departure from Earth, Neptune is Voyager's last port of call. To get there, precise navigation during the Uranus swingby is critical since an error of one mile from "corridor center" will grow to an error of 4,000 miles at Neptune. JPL's navigators believe they are up to the challenge.

However, the choice of flight path at Neptune is hardly easy. The reputation of the Voyager mission is on the line. Voyager deserves a spectacular swan song, a display of mission design skill that will yield the maximum of new knowledge about far-away Neptune, its environs, and its huge moon Triton. Since Pluto cannot be reached by gravity assist without flying nearly through the center of Neptune, that option is clearly out of the question. However, the absence of targets beyond Uranus allows a free choice of aim point at Neptune.

By arriving on schedule, Voyager will dive over Neptune's north pole less than 1,000 miles above the cloud tops and fly to a close encounter with Triton five hours later. This unique trajectory provides the navigators of JPL with a fitting challenge to test their aim on a target nearly three billion miles away — a feat comparable to a golfer dropping a thousand-mile putt. Voyager's Triton flyby distance — 6,000 miles — requires a trajectory that may pass near the possible Neptunian ring, a matter that will be fully analyzed before finalizing the flyby distance.

Of course, our solar system does not end at Neptune or even the ninth planet, Pluto. Neither does it end at the heliopause boundary where the solar wind can no longer continue to expand outward against the interstellar wind. The solar system extends over a thousand times farther to the Oort Cloud where a swarm of cometary nuclei are barely held by the Sun's feeble gravity.

Voyager 2 will race past the orbit of Pluto by the end of this decade; it may even survive a few years beyond the turn of the century. But space is vast: Traveling at 35,000 miles per hour, it will still take 20,000 years for Voyager to reach the comet swarm and many thousands of years more before it reaches other stars.



The first Uranus image released shows three satellites but virtually no features in the atmosphere of the planet. Taken on July 15 from a range of 153 million miles, this image would reveal features as small as 2,800 miles across, if they existed. The planet's rings are too dark and narrow to be visible until Voyager is much closer. JPL/NASA Voyager photograph P-28944.

Charles Kohlhase is manager of the Mission Planning Office for the Voyager Project at JPL. He worked with Dr. James Blinn on the computer graphics special effects sequences for the television series Cosmos. *Kohlhase is also the co-designer of "Wilderness: a Survival Adventure," an educational adventure simulation published by Electric Transit Co. and distributed by Electronic Arts.*

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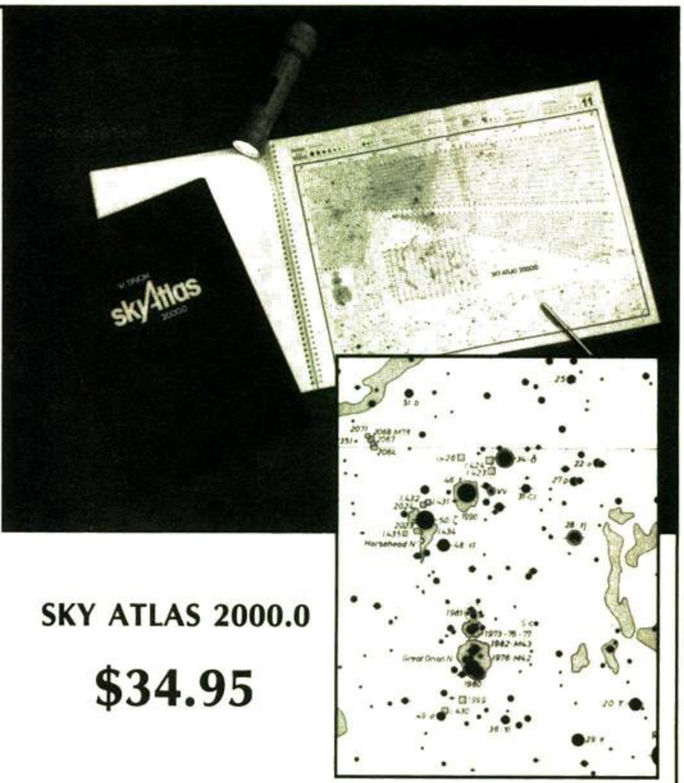

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ASTRONOMY Forum

One Night, Two Men, Three Sites, and 107 Messier Objects

The Ides of March tends to play havoc with New England's weather. With this in mind, my hopes of winning the Messier Marathon were dimmer than M-72 in morning twilight. But in spite of general pessimism caused by the weather, members of the Astronomical Society of Greater Hartford still planned to hold the event.

My partner and I had carefully selected a site and got our gear ready — now it was nature's turn to deliver some decent weather. Four earlier attempts to see all of the targets were dashed by high cirrus clouds that had skirted southern New England for the last 10 days. A clear night finally arrived — not perfect, but *clear*! A waxing crescent Moon hung high in the western sky over our East Hartland, Connecticut, observing site as I drove my VW Rabbit through old corn stalks and onto the tillage of an open field. The air temperature was 25°F and frozen stalks from last season's harvest brushed loudly against the underside of my off-road vehicle. Society member Tom Polakis, an expert deep-sky observer, met me and we were soon set up, ready for the starting gun long before twilight ended.

We were certain we could "go the distance" and — amazingly — the weather couldn't have been better. A stiff northwest wind kept reminding us this wouldn't be an easy race . . . but what the heck! M-74 slipped behind some distant trees before twilight ended, so we knew that we wouldn't have a perfect score. Using Don Machholz's article in ASTRONOMY (March 1980), we felt confident of sighting all the remaining Messier objects in no time and immediately bagged M-77, M-33, M-31, and M-32.

A long coffee break in the frigid VW prepared us for Virgo's Realm of the Galaxies — the Messier Marathoner's "heartbreak hill" where we would have to work hard and fast. Cold temperatures and high winds made the difficult seem impossible, but about an hour later we had inspected all of the Virgo objects, as well as many fainter NGCs in the area. As midnight approached, we became increasingly tired and frozen, and pondered continuing. A howling wind slewed Tom's C-8 toward the east, reminding us that there were still many miles left to run.

Concerned about our health and sanity, we finally packed up and drove home to my backyard observatory in Glastonbury. It was now midnight, but at least the winds were calm. We leisurely toured the sky with my C-11, logging in some of the Messier objects in Hercules, Ophiuchus, and Scorpius. The backyard horizon was good, but not good enough to see much in Sagittarius. Once again, we were on the move.

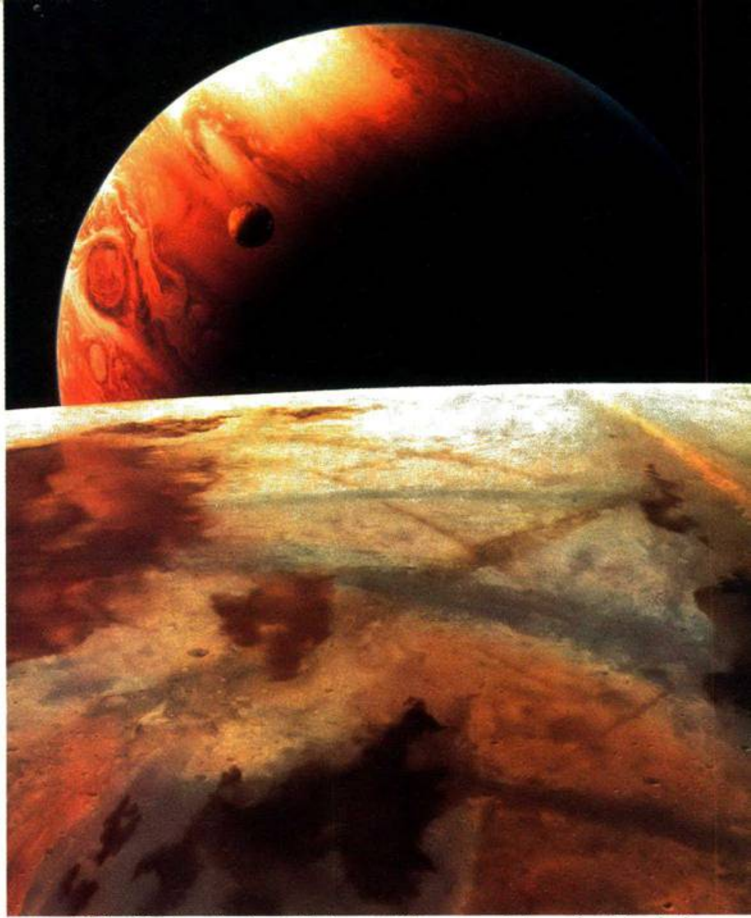
Some high ground in East Glastonbury offered an excellent eastern and southern horizon. So with the finish line in sight (we had 80 objects in the bag already!), we set up Tom's C-8 on the high ground where the wind reminded us of the cold, harsh night. In an hour, we were refreshed and began picking off globulars in Sagittarius like ducks in a shooting gallery.

No, it wasn't the zodiacal light, it was twilight! And we still had M-75, M-72, M-73, and M-30 to go! While I searched the sky, Tom rechecked his star atlas — a procedure we alternated at least 10 times. The black velvet of night was quickly turning battleship gray . . . and that darned wind! Finally, at 4:28 a.m., Tom nailed down M-75 and shortly after I found M-72. The race was over!

M-73, M-30, and M-74 got away, but the other 107 Messier objects were ours. We didn't need setting circles or electricity, just determination, cold toes, and about two quarts of coffee. It's a memory now, and a fine one at that. Tom went home and I collapsed unconscious. Would I do it again? I'll think about it, *after* I warm up!

Phil Dombrowski
Glastonbury, CT

This shot of Comet West is just one of the many spectacular photographs you'll enjoy in Solar System.



Solar System is also full of specially commissioned art, including this painting of Europa's glazed surface overlooking Jupiter.

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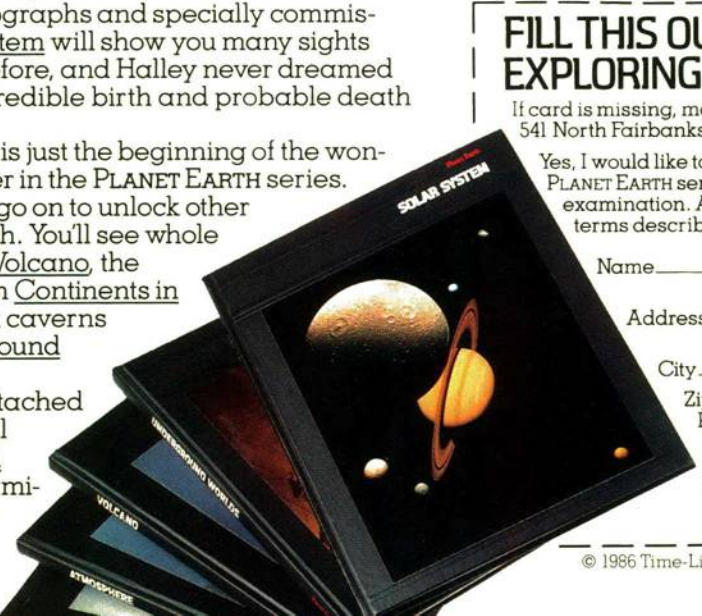

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Clyde Tombaugh is 80: A Look Back at Pluto

"That's it!"

The words came out more as a thought than as something spoken — two words no more tangible than the beautiful sight they announced, words that echoed the two starry specks offset by just the right amount on photographic plates of glass.

Only fourteen months earlier, Clyde William Tombaugh had begun his search for Pluto at Lowell Observatory, and already the speck of light for which he searched had been found. Incredible good luck? Was it too early in the search to expect such results? It made no difference, for Clyde was absolutely certain the object he had found was the new planet. In the spring of 1930, a financially-depressed world received the announcement of the new planet with joy.

When Clyde arrived at Lowell Observatory in 1928, he discovered why he had been hired: "I didn't learn about the planet search until the day after I arrived in Flagstaff. It all sounded quite exciting, of course. I knew that it would be a challenging task, and they did make me feel at home, so my apprehension soon disappeared."

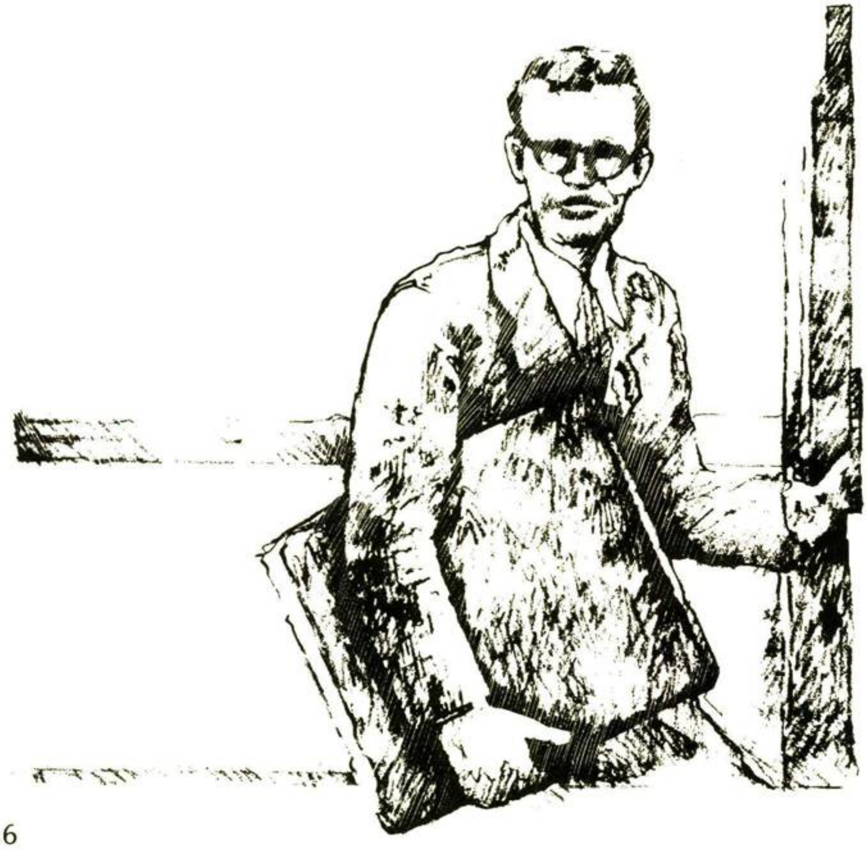
Clyde's interest in the sciences did not begin with Arizona sky but with Illinois land. "In grade school, geography was my hobby. One day, probably when I was in the sixth grade, the thought occurred to me, what would the geography be like on the other planets? I had an uncle who was sort of an amateur astronomer and lived nine miles away. I developed quite a kinship with him." With his uncle's small telescope and a little book on astronomy, Clyde began to discover the stars.

The Tombaugh family moved to the somewhat clearer sky of western Kansas in 1922. To take advantage of the better observing conditions, Clyde began to construct a telescope. His first mirror, an 8-inch, was not very good; he had ground the mirror using a post as a support, which resulted in not much more than a lesson in how *not* to make a mirror. With this experience under his belt, he made a much better 9-inch.

"I struggled, with care, with the figuring of that mirror for many weeks, but by trying to get one zone out, I'd generate another. Finally I got them all licked and obtained an excellent parabolic curve on the mirror. That really paid off, for it would take magnifying powers as high as 400 with sharp appearance.

"I started making drawings of the disks of Mars and Jupiter in the fall of 1928. I remember once I stayed up most of the night watching Jupiter, and within an hour I was aware that the markings were drifting across the disk. That was a big thrill, for I was watching a planet spin on its axis."

Yet these thrills were set against a background of family disaster. Only a few months earlier, a promising wheat crop was utterly destroyed by a freak hailstorm. This setback left the family reeling. Young Clyde had to go to work on his neighbor's farm.



That fall, Clyde applied for an observer's position at Lowell Observatory. The professional astronomers at Lowell remarked on Clyde's skill at sketching both Jupiter and Mars. Since the Mars opposition of that year had not been favorable, it was Clyde's interpretation of the intricate detail of the belts and zones of Jupiter that impressed them most. After assuring Lowell Observatory of his ability and desire to withstand long, frigid nights standing essentially in one position at the guiding eyepiece of a telescope, Clyde was offered a three-month trial as an observer.

"I loved western scenery; I had been to Colorado in earlier years. I wanted to get into scientific work, and with the money I had made running my neighbor's combine, I bought a railroad ticket to Flagstaff. I couldn't afford a Pullman, so I rode 28 hours in a chair car. I didn't have enough money in my wallet for a return ticket — this was quite an adventure!"

Clyde not only discovered Pluto, he also devised the means of finding it. Unlike what had been done previously at Lowell, Clyde wanted to photograph the sky selectively, looking only at the part that was at opposition on any given date. This is where the speed of a planet's retrograde motion instantly betrays its distance from the Sun: the farther out an object is, the slower its retrograde motion and the smaller the day-to-day change in its position.

To aid the search, Lowell Observatory had acquired a blink comparator, a device that holds two glass photographic plates. The user sits at an eyepiece, aligns two plates taken of the same field on different days, and systematically compares them. An electric shutter shifts the view from a small area on one plate to the corresponding area on the other plate and back again several times a second. Ideally, the "blinker" looks at one plate and then the other without really being aware that there are two plates. If, however, one plate has been taken under better conditions than the other, the unmatched set doesn't "blink" very effectively because every star appears to change.

Clyde worked out a formula for lengthening exposures to correct for varying degrees of atmospheric absorption so that two plates taken under differing conditions could be compared. Then only the occasional flicker of a variable star or the electric, jittery hop of a moving object in the field would announce that something had been found.

As long as the plates were perfectly

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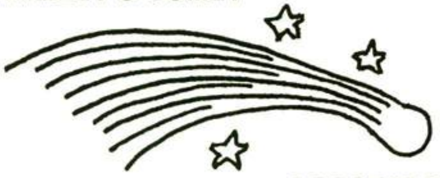

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matched and the machine's eyepiece was in good focus, blinking didn't tire Clyde's eyes. The real enemy was tedium. "The richest regions in Gemini would run 400,000 stars per plate, and I'll tell you, that's a horrendous number of stars to go through. It took two-and-a-half to three weeks to blink one plate. Depending on my observing program, I could do as much as six or seven hours of net blinking per day, which was pretty severe. I took frequent rest periods, otherwise my attention would lag and I could miss something."

Perhaps because the professionally trained astronomers at Lowell were looking for an object of a certain mass and probable brightness, they blinked right past an image of Pluto a full year before its discovery. When Clyde was hired, their search had pretty well run out of steam; Planet X, thought to be brighter than Pluto actually was, hadn't surfaced in the first photographic surveys. Prospects looked bleak.

"About 100 [plates] were stacked up and none of them were being blinked. Dr. Slipher [the director of the observatory] was getting desperate, and so he came down to my office after my June run of night work to say that he wanted *me* to blink the plates. I shuddered when I heard that. Seeing all those stars, it seemed like a horrible, tedious task, and I wasn't happy about that at all. I did a lot of thinking about it and worked out a careful observing strategy during the summer of 1929. In the fall, I started hitting the opposition point. I would march eastward about 30° each month to keep up with it."

On February 18, 1930, Clyde began his day around 9 a.m. A bright Moon had prevented any observing the night before, so a full day of blinking could ensue. At four o'clock in the afternoon and one-quarter of the way through a pair of plates, he noticed an object appear, then disappear.

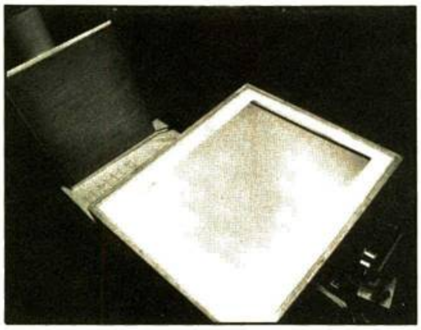
"I saw a little image popping in and out; I looked to one side and saw another one doing the same thing. Were they both on the same plate or were they on alternate plates? I stopped the automatic blinker and blinked by hand the different plates. I noted the dates of the plates. The image on the earlier plate was to the east, the one on the later was to the west. It was retrograding as it should do and the amount of the shift was a six-day interval. Knowing the scale of my plates, I knew instantly that the object was way *out beyond* the orbit of Neptune.

"Immediately I got out a plastic *milli*meter ruler to measure the shift more accurately. I knew it was beyond Neptune so I had a better idea about how far out it was. Of course there still was a chance of a [plate] defect or false planet suspects, so I took one of the plates off the machine and put a third plate on from another date to see if the image would be in the right place and if it would be consistent with the amount of shift on the pair I was examining. It was perfectly confirmed. I was 100 percent sure."

What thoughts must have been swimming through the discover's mind at that instant!

"For 45 minutes I was the only person on Earth who knew about Planet X! I was walking on the ceiling."

Across the hall, Dr. Lampland, one of the other astronomers, sensed that something had happened when the steady blinking stopped. "I was about to reprimand him for goofing off," Lampland was later quoted as saying, "but he had a good excuse for it." With Clyde's call, he rushed over to look.



This "B" plate, stored in Lowell Observatory, was blinked against the "A" plate to discover Pluto. Photo by D. Eicher.

"I went down to the other end of the building where the director was," Clyde recalled. "His office door was open and he was working on some papers on his desk. I paused a moment to get myself contained. I walked in and said, 'Dr. Slipher, I have found your Planet X.' He rose right up out of his chair with a curious expression of elation and some reservation. I said, 'I'll show you the evidence.' He immediately started down the hall and I had to step lively to keep up with him. Saying 'it looks pretty promising,' Lampland turned the comparator over to Slipher to examine."

Keeping the find a secret was Clyde's next challenge. He didn't even tell his parents. "If it leaked out and it didn't turn out to be a new planet, the observatory would be in an extremely embarrassing position. We couldn't afford to do that." Two nights later, the eyes of V.M. Slipher, C.O. Lampland, and Clyde Tombaugh looked for the first time on the solar system's newest addition.

Because Pluto was smaller than anyone had predicted — too small, in fact, to account for the perturbations of Neptune that originally led astronomers to suppose there was a Planet X — the search continued another 14 years. The by-products of the search turned out to be almost as important as the planet itself. In 1932, Tombaugh discovered a new globular cluster, a faint object 103,000 light-years away. Another major discovery was a supercluster of some 1,800 galaxies. In addition, he found several smaller clusters of galaxies, five open star clusters, and, within our solar system, about 775 mostly unconfirmed asteroids and one comet. While these finds were as astronomically significant as Pluto, the new planet naturally captured the public's attention.

In 1978, James W. Christy discovered that Pluto has a moon, now named Charon. "Discovery," Christy later would write, "is where the scientist touches Nature in its least predictable aspect. It discloses to us the regularities of Nature, but in itself, discovery is fickle, striking at the unexpected moment."

When we think how a tiny ball of ice in the outer solar system utterly changed the life of a farm boy from the Midwest, "touching Nature" has an irony that's both amusingly literal and wonderfully appropriate.

Living in a large old house on the southern edge of Las Cruces, New Mexico, Clyde and Patricia Tombaugh enjoy busy lives. Patricia is an accomplished painter and Clyde works on articles and a mountain of correspondence. He also spends a good portion of each day in his office at New Mexico State University. The Tombaughs share their home with some pets, including a black cat called Pluto. ("The plutocrat," Clyde explains, adding that it's "the only catadioptric telescope in the house.")

Clyde's career has included much more than Pluto and Flagstaff. At White Sands Proving Ground he ran the optical tracking service for missile launches. Later, at New Mexico State, he set up a planetary patrol program that has provided some of our finest and most detailed ground-based photographs of the major planets.

Now in retirement, Clyde enjoys the fruits of his productive life and the chance to go back to his own telescopes and enjoy the sky he loves. With his homemade 16-inch reflector, which is mounted on a great scaffolding of steel and wood in his side yard, Clyde gets first-class views of the planets. When he wants to hunt down deep-sky objects, he hauls out a small reflector mounted on a lawn mower chassis.

Eighty years old this February 4th, Clyde has returned to his earlier status as an *amateur astronomer* who loves the sky he watches.

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Halley: Lost in Perpetual Twilight?

Remember meteor showers? Remember the northern lights? Remember the night sky, alive with thousands of shimmering stars right down to the horizon? If you are over 30 years of age, maybe you do. But if you're younger, chances are you don't, unless you live in a rural area or have been lucky enough to catch a moonless, cloud-free night on a camping trip.

If you're over the age of 80, maybe you remember a spectacular comet by the name of Halley. Comet Halley is back in our vicinity, but don't expect to see an awe-inspiring sight of this most viewed of all comets. The reason for this is, in part, pollution. Dust particles in the air block and scatter incoming light just as a dirty window does.

Another type of pollution that affects the viewing of the wonders of the heavens is light pollution. Mercury vapor, high-pressure sodium, and quartz halogen lamps and floodlights direct some of their illumination upward where it is scattered by air molecules and dust particles. This reduces the contrast between the natural sources of light (stars, the Milky Way, meteors, etc.) and the sky "background" (our atmosphere).

A little bit of haze or light can ruin the appearance of meteors and comets. Faint meteors, which are quite numerous, can no longer be seen. Diffuse objects such as comets are obscured or completely hidden from view. The Milky Way, a startling sight as seen from under a dark sky, may not even be visible at suburban locations.

Viewing this apparition of Halley will be particularly difficult for observers above 40° north latitude since the comet will be at its brightest when it is only 10° above the horizon. The viewing problems created by light pollution are greatly magnified near the horizon. When you look at the sky directly overhead, you are looking through about ten miles of atmosphere; when you look out at the horizon, the air is about one hundred miles thick. Consequently, there are many more light-scattering molecules and dust particles to contend with.

Think back to what your neighborhood looked like at night just five or ten years ago. Chances are there has been quite a change. The tremendous increase in outdoor lighting has come from new communities as well as existing ones that now have more and brighter lights.

You might be thinking, "I'll leave the bright lights of the city and drive out to the country to get a clear view of Halley." But rural areas have seen an increase in development, too. And the pervasive sky fog from the sum total of all outdoor lighting is present many miles from the city. Even though you may look at the country sky and marvel at all the stars you can see compared to what you're used to in the city, it will be a poor substitute for a truly dark site. Comet Halley may be visible from such a location, but no matter how good it may look to you, you will be missing the full splendor of this historic visitor.

This raises some questions about outdoor lighting. Is it used only when necessary? Is it brighter than it has to be to accomplish its intended purpose? This is one type of pollution that would not cost anything to reduce; in fact, it would actually save money.

I know that many people believe light has the same effect on a criminal as a crucifix does on a vampire, but a study by the National Institute of Law Enforcement and Criminal Justice (part of the U.S. Department of Justice) found no statistically significant evidence that street lighting reduces crime. What it did find, though, was that lighting decreased the fear of crime, giving a false sense of security.

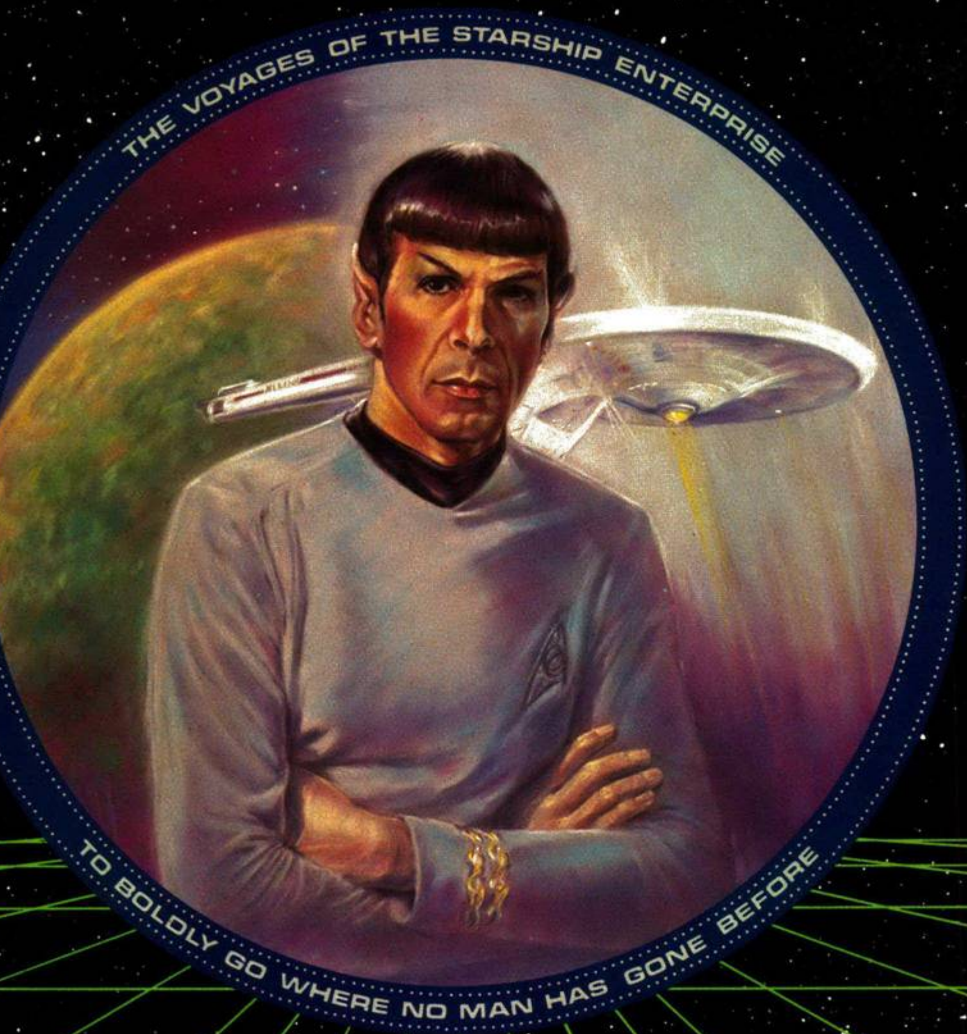
I wonder, too, if the cost of bathing a building or sign with decorative lighting all night produces enough profit to justify its cost. Does showering an intersection with a zillion lumens really make it safer for motorists? Must so many lights be kept on from dusk to dawn, or could most be timed to turn off after about 10:30 p.m.?

You are the one who pays for this perpetual twilight in tax dollars and increased prices for products and services. (Did you know that in many municipalities it is the electric utility that is asked to provide the recommended location and number of street lights?) Why, in this age of increasing taxes and decreasing energy resources, do so few seem to question such expenditures?

I have been an amateur astronomer for nine years, and in those nine years I have seen the night sky grow brighter and brighter. I am not optimistic about the future. Reducing light pollution is not a high priority for most people. I find it sad, though, that the magnificence of the night sky — our window on the universe — is being reduced to a facsimile projected onto the ceiling of a planetarium.

Many people will never view with their own eyes the delightful sites of meteor showers, the Milky Way, the northern lights, the Andromeda Galaxy, the Orion Nebula, and Halley's famous comet.

Robert Job
York, PA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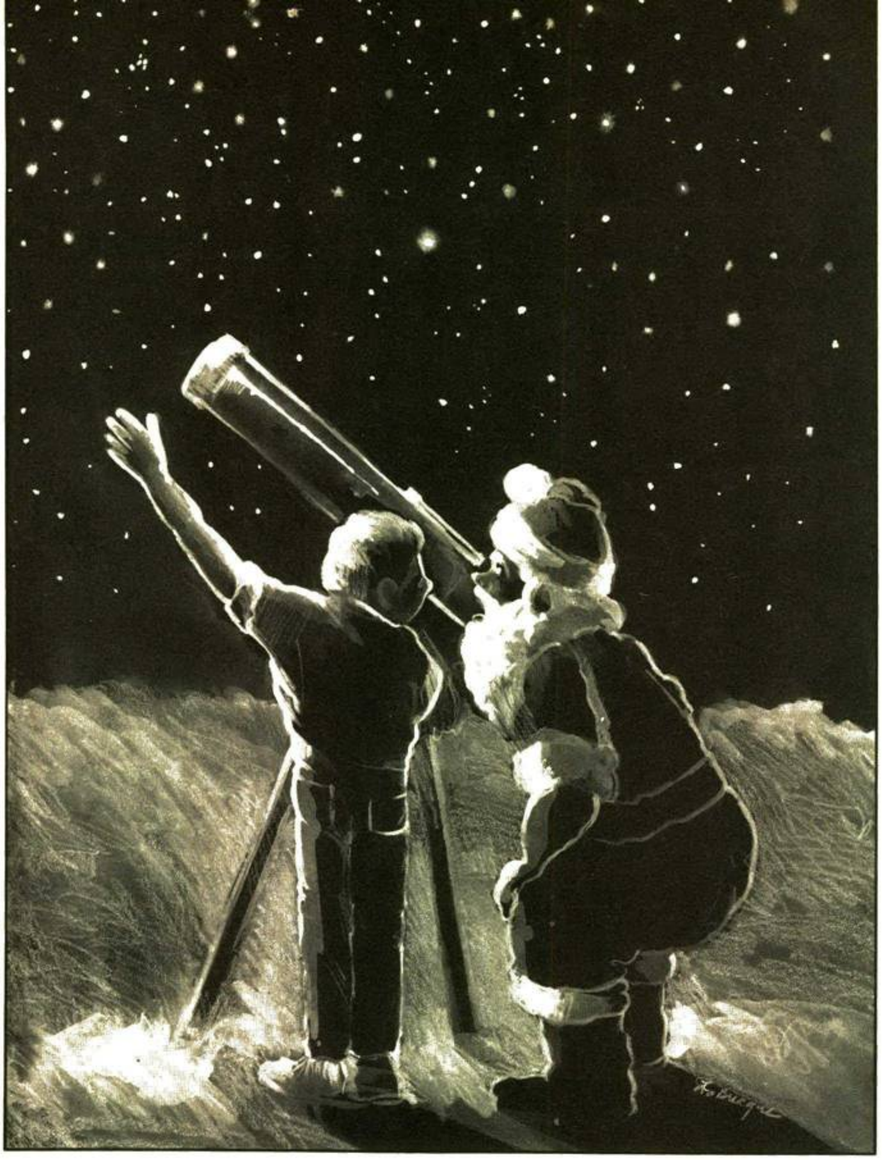

Christmas In August

Last night I discovered Christmas in August.

As a six-year-old boy growing up in the small, light-pollution-free town of Ravenswood, West Virginia, I would often lie on hot summer nights in the porch swing at my grandfather's house and marvel at the Moon and the vast, mysterious universe that challenged me overhead. I remember wondering if man might ever "touch" the Moon. Somehow, in Ravenswood, it seemed close enough to touch.

I remember hearing my grandfather talk about his first cousin, a man named Ritchie, who came from Tuppers Plain, Ohio, and who "helped build Mount Palomar." As years passed, my interest in the stars became dormant, yet life as a child under that star-filled sky and my fascination over somehow being related to Ritchie had planted the seeds of interest which led me to decide, in my forties, that I was ignorant about the universe. I began haunting all the libraries around Pittsburgh, reading everything I could find on astronomy. I've always hesitated on buying a telescope, though, because of the costs involved and the uncertainty about which instrument would be right for me.

Several weeks ago I learned that David, the son of my next door neighbor, was involved in amateur astronomy. When I first learned of David's interest, I gave him all of my issues of ASTRONOMY from the last four years. I confess that I had an ulterior motive.

Last night, while sitting alone stargazing and watching satellites pass overhead, David came over to my patio to return several issues. He said his dad had given him a subscription to ASTRONOMY a few months ago, so he was returning duplicate issues to me. I invited "old" Dave to sit down and compare notes on what we both knew about astronomy. I gave him a quick, discreet test, asking questions like: "How far is the Moon from Earth at apogee and perigee?" and "How many light-years in a parsec?" I became convinced that David had nothing to fear (nor did I) because our knowledge seemed about par.

I was taken aback when Dave told me that his score on the SAT was such that he had been admitted to an astronomy summer camp at the University of Arizona. I decided to play it "cool" and do more listening than talking. I thought he would never ask but finally he said: "Would you like for me to run over and get my telescope, Mr. Silliman?" Like a kid, I said "Sure!"

David and I talked for nearly two hours, identifying stars and discussing things like whether the correct pronunciation is Vee-ga or Vay-ga, and the possibility of a tenth planet in our solar system. We stopped talking occasionally to look through Dave's telescope at the Moon and the rings of Saturn, which were about two o'clock to the right of the Moon. I kept saying "How beautiful . . . how beautiful!" every time I took my turn. At long last, David accepted the fact that we were kindred spirits and said, "Ya know, Mr. Silliman, you ought to go with me to my amateur astronomy group's sky party tomorrow night at South Park." I asked him how the light pollution problem was there and he said, "I never thought about it — with my telescope, I can see enough to make me happy."

Tonight, my newly-discovered astronomy buddy, David Shuman, and I are going together to the South Park Sky Party sponsored by the Bethel Park Amateur Astronomy Club.

What I won't tell David is that I have shied away from amateur astronomy parties in the past because I was afraid that I might show my ignorance. Maybe if I keep my eyes open and my mouth shut, and let David be my guide to the universe, I might get up the nerve to buy my first telescope.

Thank God for the Davids of this world who are brave enough to do what I failed to do — jump with both feet *and* a telescope into that vast and wonderful universe that is ours for the asking at any age. Thank God that David accepted me at my age as someone he was willing to share his interest in astronomy with. David Shuman is 13. I am 56. Tonight, thanks to David, I will go to his star party and we will both stargaze in awe, like children, from a planet called Earth.

If you should meet David at some future star party or at work in some observatory, please don't tell him how much more he knew about astronomy than Mr. Silliman. I'm old enough to be the kid's grandfather. You'll know David immediately: he has red hair and . . . a telescope. If you should hear or read about my smart neighbor who made it big in astronomy, just remember: it was I who first told you about him — and his telescope.

— *John R. Silliman*
Pittsburgh, PA

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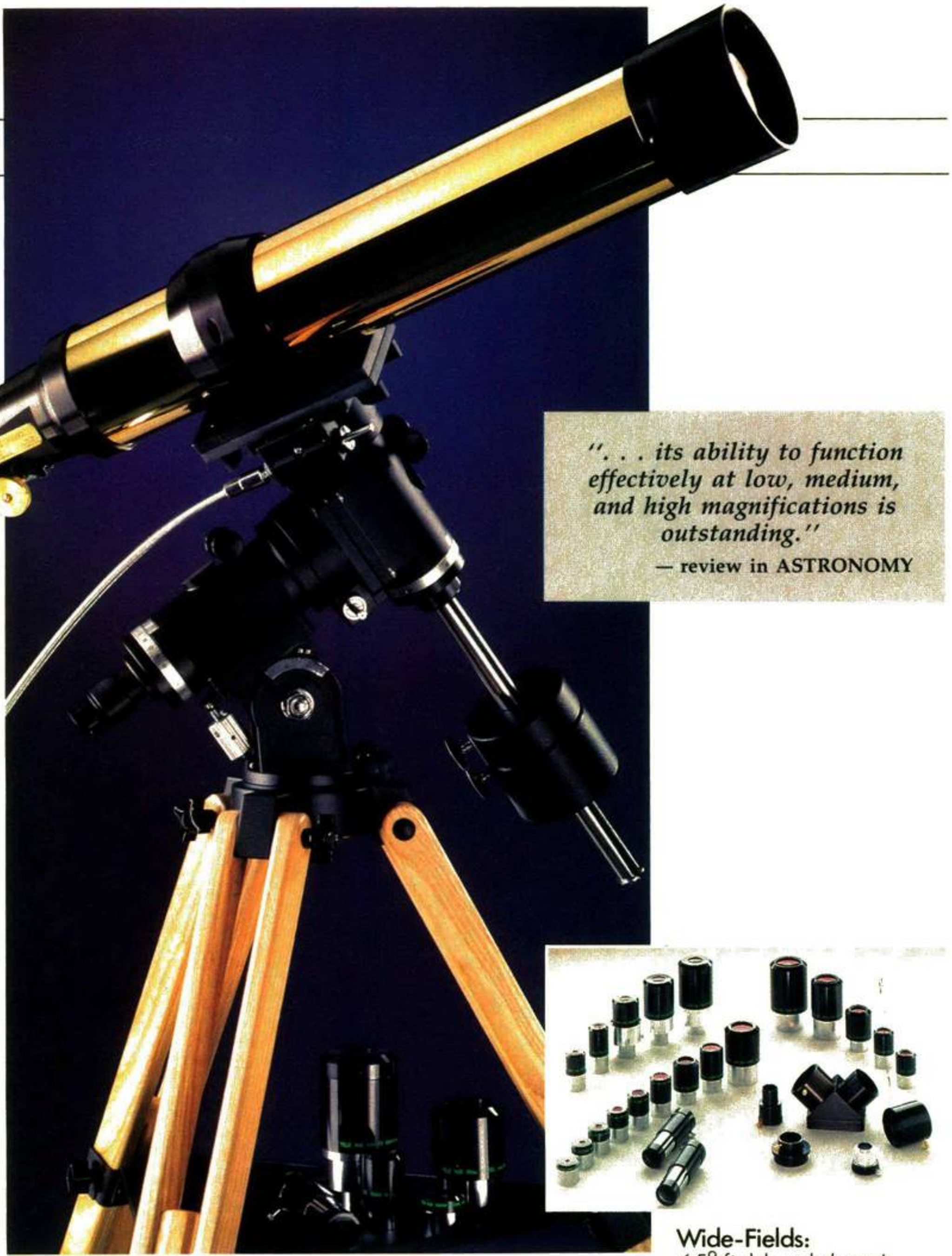

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Voyager's Show of Shows

Sir / I am so tired of all this Halley hysteria and hoopla that I'm surprised we are not experiencing the same crazy stupor that prevailed in 1910. May I remind the Halley's Comet crowd that we're in for a surprise much greater and far more interesting than the comet's return — Voyager 2's flyby of Uranus, an object never before seen in detail by human eyes.

Halley's Comet may be a once-in-a-lifetime experience, but how often do our solar system's members align themselves so that a space probe can gravitationally propel itself from one to another? Once in a very long time. Yet even at our planetarium there is not one shred of light on the subject. Halley, however, is having its showcase even before it gets here; there is even a sky show on comets alone that will be on for months.

This is insulting to NASA, which built Voyager 1 and 2, and to the commendable workers at the Jet Propulsion Laboratory who have prepared for this great moment for nine years with an accuracy that is almost astronomical.

I only hope that once Voyager 2 does its third planetary show of shows, Halley will be forgotten.

M. Tepper
Chicago, IL

Another Ogre?

Sir / I would like to comment on the Forum piece titled "Chasing the Ogre" in your April issue.

To date, I have sighted nine flashes in Lepus near the planetary nebula IC 418. These objects seem to be like those observed in Perseus by Bill Katz. The flashes occurred when Lepus was close to the western horizon, and I noticed the majority of them out of the corner of my eye. Estimated magnitudes averaged from −2 to 0.

If anyone has information on bright flashes in Lepus or other constellations, I'd greatly appreciate receiving it.

David M. McWhorter
Ohio Valley Astronomical Society
Route 3, Box 310
Proctorville, OH 45669

Mars Observer Mission

Sir / In the September 1985 issue of ASTRONOMY, the AstroNews note on the Mars Observer contains a few minor errors in the description of the mapping spectrometer instrument.

The instrument's spectral coverage is correctly described as being 300 to 4,300 nanometers. However, visible light is generally recognized as ranging from about 430 to 690 nanometers, not 38 to 78 nanometers as described. The casual reader might miss the important point that the instrument's spectral coverage includes the visible region of the spectrum and extends both shortward into the ultraviolet and longward into the infrared. The instrument works primarily in the infrared since this is where many materials exhibit their strongest spectral signatures; its maximum resolution is about 1,000 feet on the martian surface and the swath width is about 25 miles.

The instrument proposed by JPL for the Mars Observer mission is known as the VIMS (Visual and Infrared Mapping Spectrometer). Though the instrument is commonly referred to as a mapping spectrometer, it's more accurate to call the device an *imaging* spectrometer since that's the type of data it will collect.

Viking Orbiter photography gave us global maps of about 97% of Mars at visual wavelengths to a resolution of about 1,000 feet. The Mars Observer imaging spectrometer could photograph the planet in more than a hundred spectral bands at the same resolution as the Viking photos. This will let us map the rocks of Mars by their elemental, chemical, and mineralogical species, and distinguish lithologic units by their spectral reflectances. In addition, the long duration of the mission will make it possible to monitor seasonal changes, especially water and carbon dioxide frost and ice formation at the poles.

Though global mapping of the composition of the martian surface is a scientifically exciting prospect, we'll also be getting back spectacular color photos comparable in quality to those from Viking. The Mars Observer mission may be a budget operation compared to Viking, but the data acquired promises to be exciting to both the scientist and the layman.

James Duval
California Institute of Technology
Pasadena, CA

Dark-Sky "Hot-Spots"

Sir / After two consecutive years of attending the Texas "Cloud" Party, I learned an expensive lesson: the month of May is not the time to observe in the Davis Mountains since clouds, rain, dew, and bad viewing seem to be the order of the day or night.

There is, however, an alternative that may be more sensible and is certainly a far less expensive compromise for springtime observing in the Southwest.

Texas boasts a rather impressive number of state parks that have surprisingly dark skies and better conditions for observing early in the year. One such facility is Dinosaur Valley State Park in Glen Rose. In addition to a decent night sky — the only source of light pollution is a nearby nuclear power plant — the park has some fine hiking trails and paved parking areas for observation. Astrophotographers will also appreciate its solitude and lack of late-night foot traffic.

But what makes Dinosaur Valley

especially attractive is its proximity to the Dallas/Fort Worth area, which offers substantial entertainment and lodging facilities in the event the weather refuses to cooperate.

This isn't the only good park in the region, but one of many. Check 'em out!

Edward W. Eaken
Akron, OH

— How many readers know of other sites with dependably good observing conditions? (Let's take "dependable" to mean good enough that you'd risk your annual vacation on it.) If you know of any such places, drop us a line.

Looking for a Few Good Observers . . .

Sir / With the help of professional and experienced amateurs, I am ready to embark on a visual search for extragalactic supernova and am looking for a few keen-eyed amateur astronomers who might be interested in joining an "Amateur Supernova Search Network."

To some extent, professional astronomers rely on amateur findings, which constitute valuable records. A supernova search program involves the methodical searching of a specific area over intervals of time. With such a network, sections of the sky can be scrutinized every night from different locations. The thrill of discovery and the aesthetic pleasure of finding a supernova has personal payments beyond compare.

For more information, send a self-addressed, stamped envelope to:

Steve H. Lucas
3736 W. 169th St.
Country Club Hills, IL 60477

Bring Out Your Telescopes!

Sir / I gave a star party for a local group last week — a new idea for this town. In the publicity, I suggested that those who had telescopes bring them along. To my amazement, they did just that — from dime-store jobs to Sears, from family antiques to plush Criterions.

Obviously some of these scopes hadn't been used recently, yet they delighted their owners. Talking to participants, I got a solid picture of what had happened: they'd bought the instruments and become discouraged after a few nights of failure, leaving them to the dust of the attic.

But things changed the night of the star party after a little help on which screws to turn, where to point the telescope, and what to look for. ("No, ma'am, those four stars are not a defect. They are the moons of Jupiter.")

Y'know, it might be a good idea if other star parties asked people to bring their old scopes along, too. Who knows how many lapsed observers could be reclaimed?

Walter Scott Houston
East Haddam, CT

Mnemonics Anonymous

Sir / Thanks to Fred Schaaf (Eye on the Sky, May 1985) and John Llewellyn James (In Focus, September 1985), I've stayed cool during a heat wave trying to concoct a mnemonic device for the names of the seven bright stars in the Big Dipper.

If you go from the handle tip to the pointers and recall "Alcohol in My Sore Alimentary May Greatly Affect a Miracle Dubiously," then you'll have a fighting chance of remembering Alkaid, Mizar, Alioth, Megrez, Phecda, Merak, and Dubhe. (So what if Alcor's missing — it's too dim anyway.) Or if you prefer the reverse order, simply use "To Be of Miraculous Effect, Make All the Misers Alcoholics." Cheers!

Evans Burn
Sherborn, MA

Oooops!

Our story titled "Southern Schmidt Photos" in the May 1985 issue incorrectly attributed the 3.9-meter Anglo-Australian Telescope to the Mount Stromlo and Siding Spring Observatory; the telescope is located on Siding Spring Mountain but is operated as a separate facility.

Also in the May issue, the photo on page 83 was taken by Dorothy Murphy. It shows a group from the Astronomy Centre of the Darling Downs Institute of Advanced Education, Queensland, Australia, preparing to observe the occultation of an 11th-magnitude star on June 15/16, 1983.

Our apologies for the errors!

Behind the Scenes

Viewing Halley

Comet Halley seems to have begun brightening rapidly sometime in late September or early October. The first naked-eye sighting occurred on November 8 when Stephen Edberg and Charles Morris glimpsed the comet, reporting it as a very faint patch of light. When Steve called ASTRONOMY to report his sighting to us, he emphasized the clear skies and 7,000-foot elevation of his observing site. Their sighting made the radio and TV news, and even appeared in *Time* magazine.

During the week that followed, we heard other reports of sightings from the West Coast. We watched and listened while the media touted the passage of Halley's Comet past the Pleiades. Photographs started rolling in: first the black and white shots, then the color.

Meanwhile, here in Milwaukee, it rained. It even snowed.

Sunday, November 18th, dawned dreary but the sky cleared by noon. Assistant Editor Dave Eicher and I checked the weather forecast: clouds were expected but they wouldn't arrive until midnight. I loaded my trusty 12-inch reflector into the van and at 7:30 p.m. we headed for our "secret" observing site at a boat launch where the road from the town of Lake Church runs into Lake Michigan.

I hadn't expected a crowd. There were half a dozen cars, a small crowd of people, several binoculars, and two small telescopes — and all those people were observing the comet. I set up my 12-inch telescope.

The comet looked great. It filled the whole 85x field of view — over half a degree. It was big and bright with Dave's 20x80 binoculars and easy in the 7x35s being passed among the people at the end of the road.

When the crowd left and the Moon finally set, we inspected Halley's nucleus for jets or other signs of activity but saw none. It occurred to me that anything so bright in the 12-inch might . . . . Well, to make a long story short, we could see it naked eye. I'm sure this was no great observing feat since the comet would have gained more than half a magnitude in the ten days after Edberg and Morris saw it, but it was nice to have seen it.

The clouds rolled over at 10:30 so we loaded the telescope back into the van. Half an hour later it started to rain again.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

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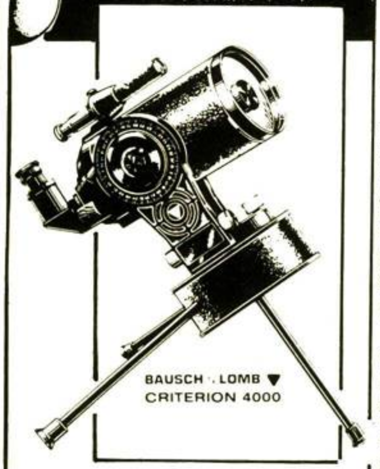

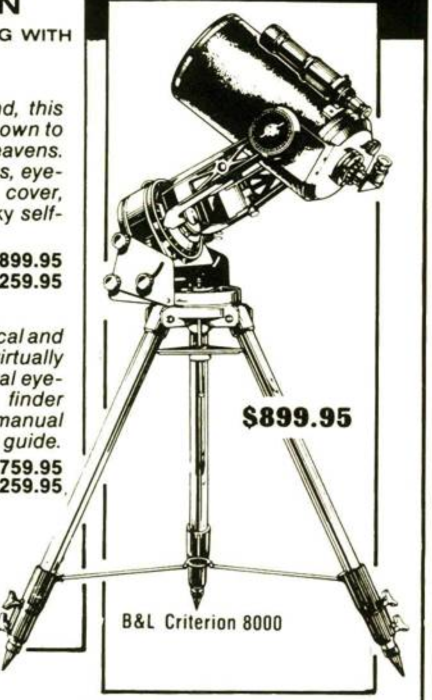

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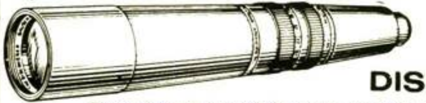

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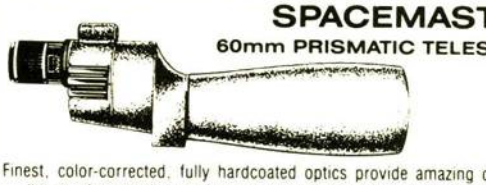

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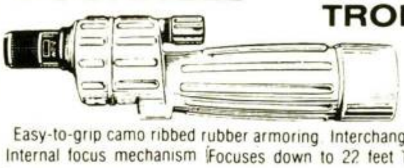

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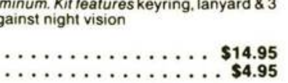

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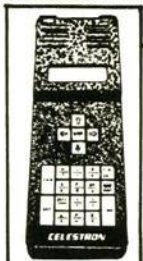

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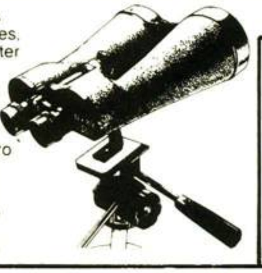

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Photography in Astronomy

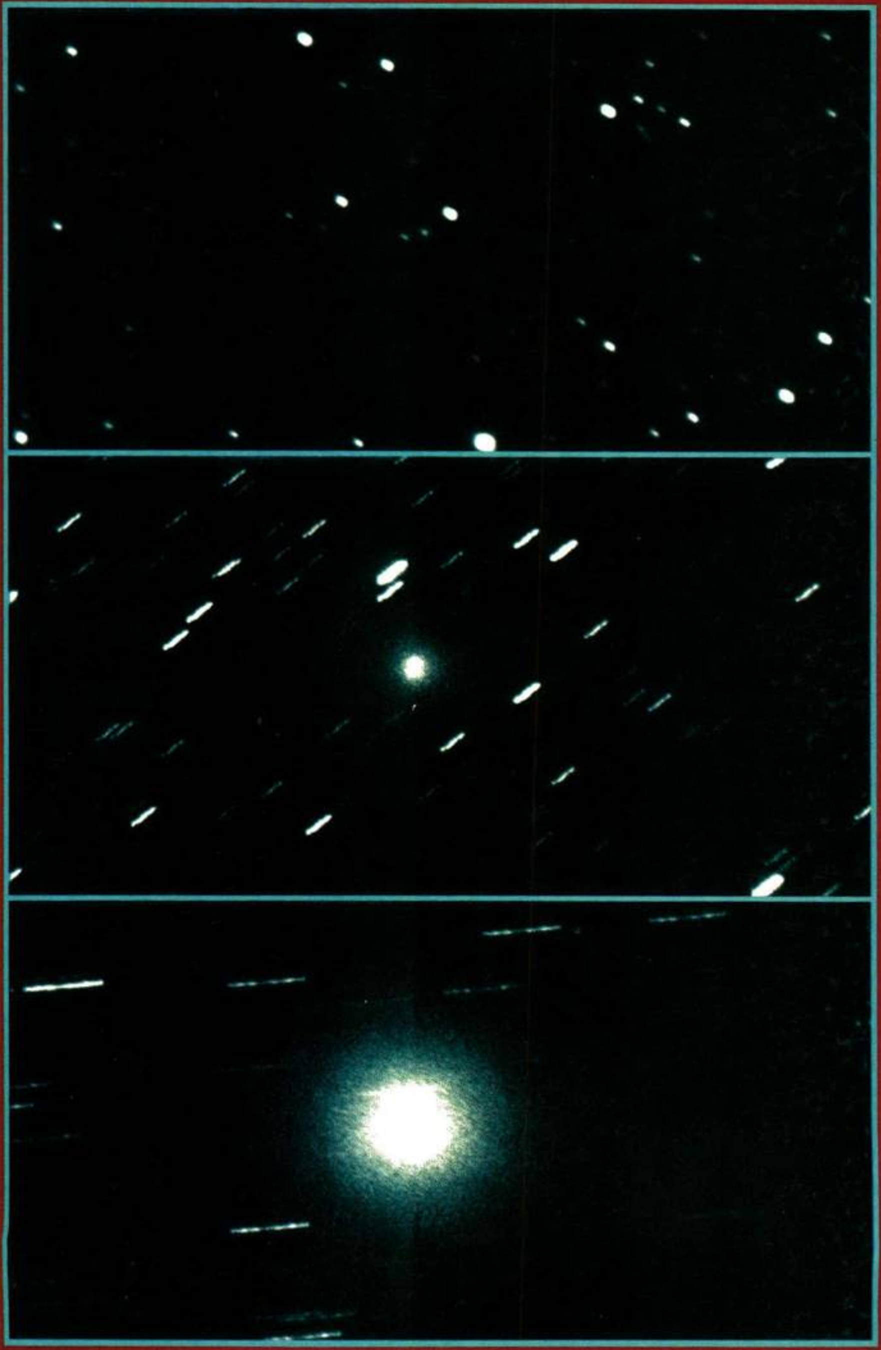
Halley Draws Nearer

After a slow start, the solar system's most famous comet brightened dramatically during October and November 1985. In fact, Halley's brightness increased so much that it not only recovered from being dimmer than its predicted magnitude but it became *brighter* than predicted by a considerable margin.

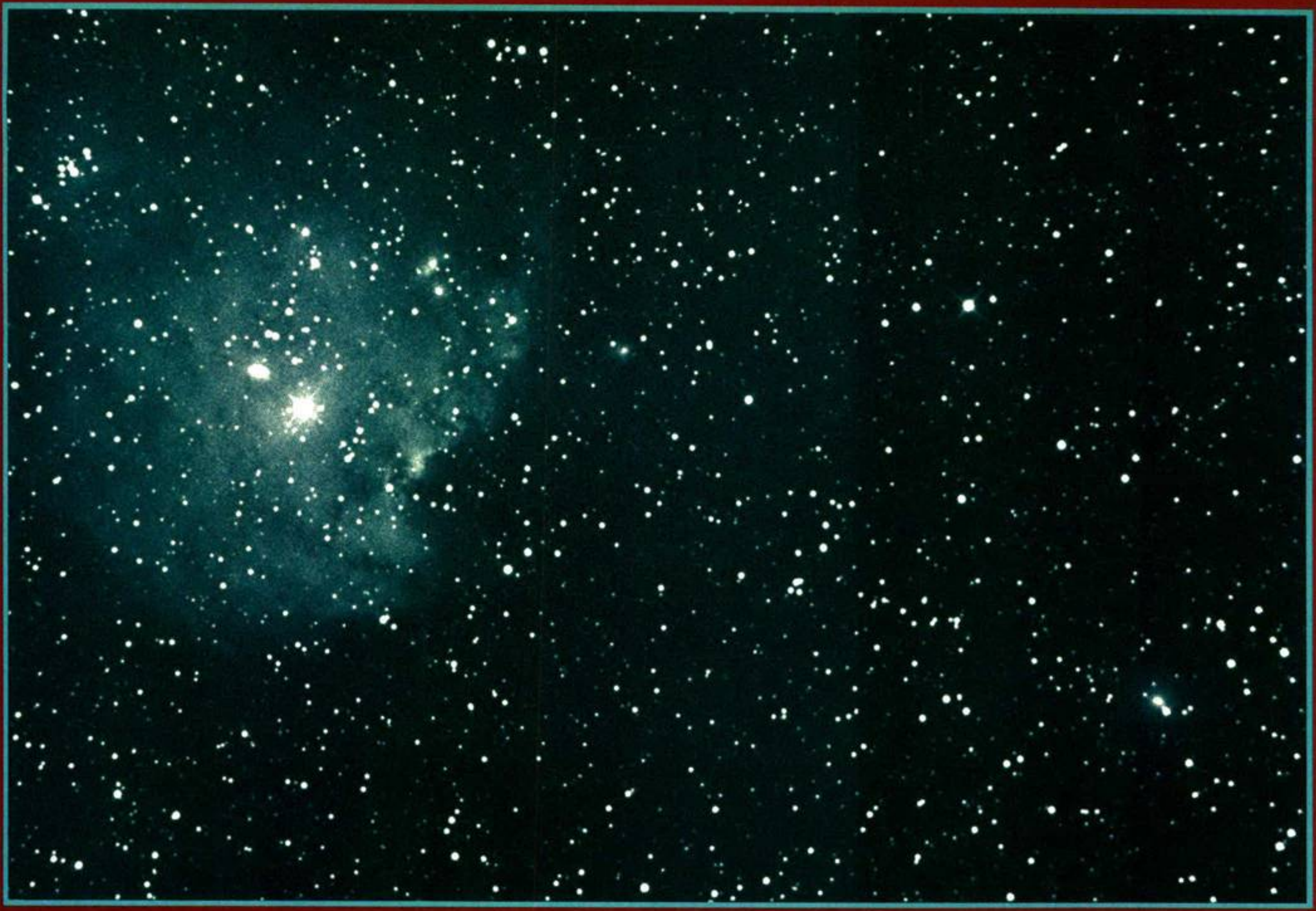
This sudden cooperation on Halley's part meant observers and photographers had a bright, impressive object as their target. Halley was no longer merely interesting just because it was Halley. By mid-October, it shone at 8th magnitude and had developed a small tail. The result was that thousands of people spotted Halley for the first time, including practically every backyard astronomer with a single clear night.

Astronomers were surprised at the sudden brightening, but they were even more surprised when the brightening continued through November. By the 8th, Comet Halley had reached magnitude 6.5 and was spotted — for the first time in 75 years — with no optical aid. Steve Edberg and Charles Morris saw Halley as a "big fuzzy spot" from the 7,000-foot summit of Mt. Waterman in California. By November 20, Halley reportedly shone at magnitude 5.3 and spanned more than 30′

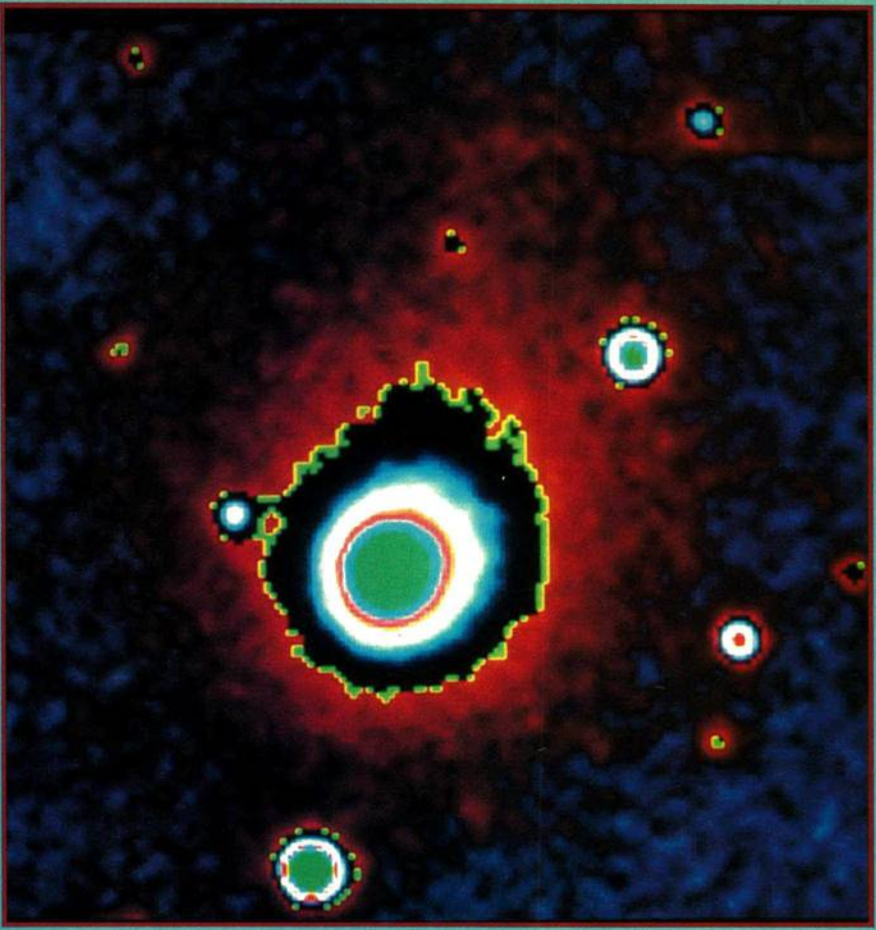
Continued on page 47



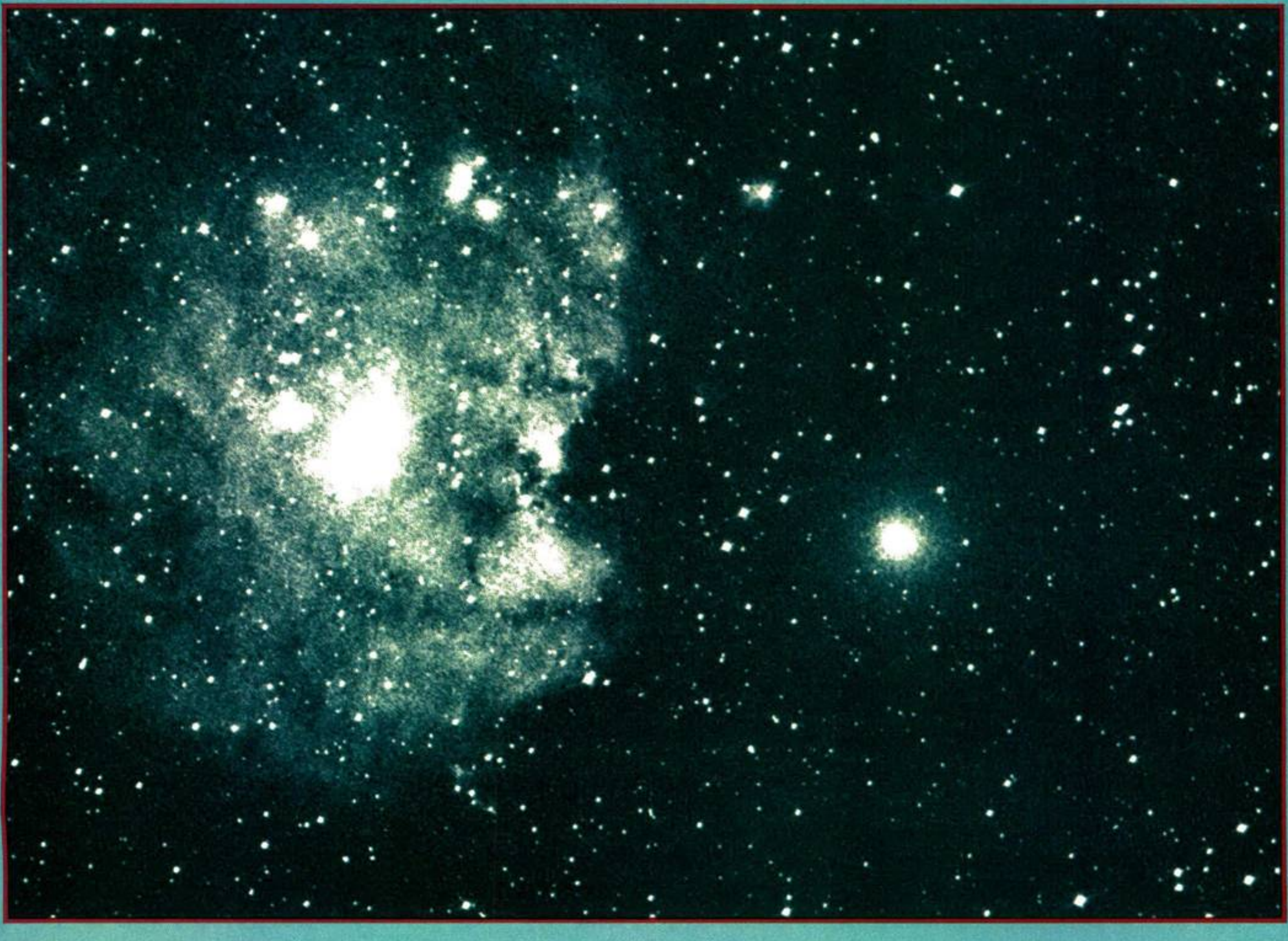
Left: Between September and November 1985, Comet Halley really came to life. These three photos, all having the scale 13 arc-minutes per millimeter, show Halley as it brightened from a 14th-magnitude smudge of light into a naked-eye object on September 15 (top), October 17 (middle), and November 8 (bottom). Photos by John Stull using a 20-inch f/5.5 reflector at Alfred University Observatory. Each is a 20-minute exposure on 103a-F film. ***Right:*** **On November 7, Halley appeared as a 7th-magnitude bluish white cotton ball in binoculars and telescopes. Photo by Jim Riffle using a 12-inch f/5 Astro Mak camera and a 5-minute exposure on Konica SR 1600 film.**

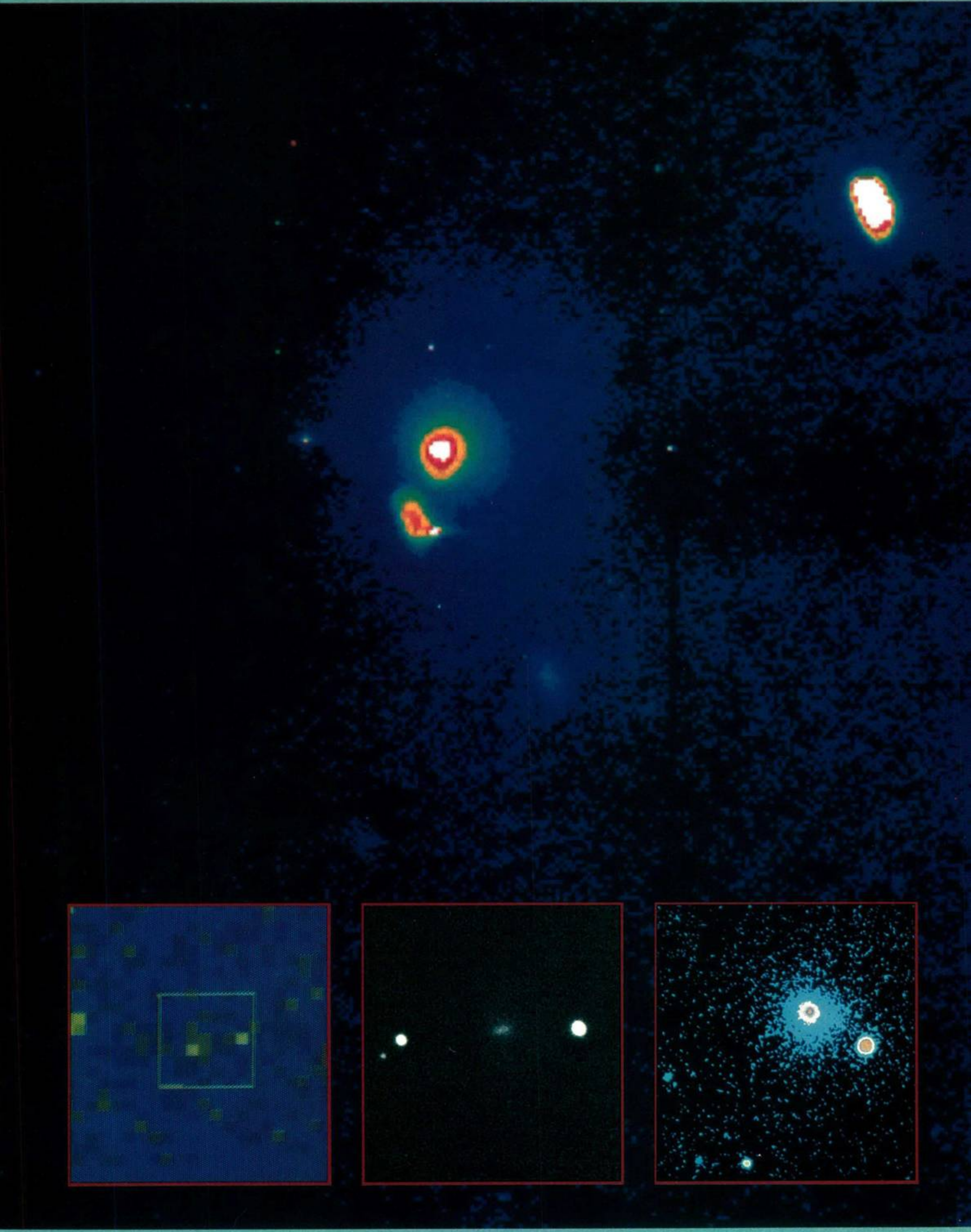


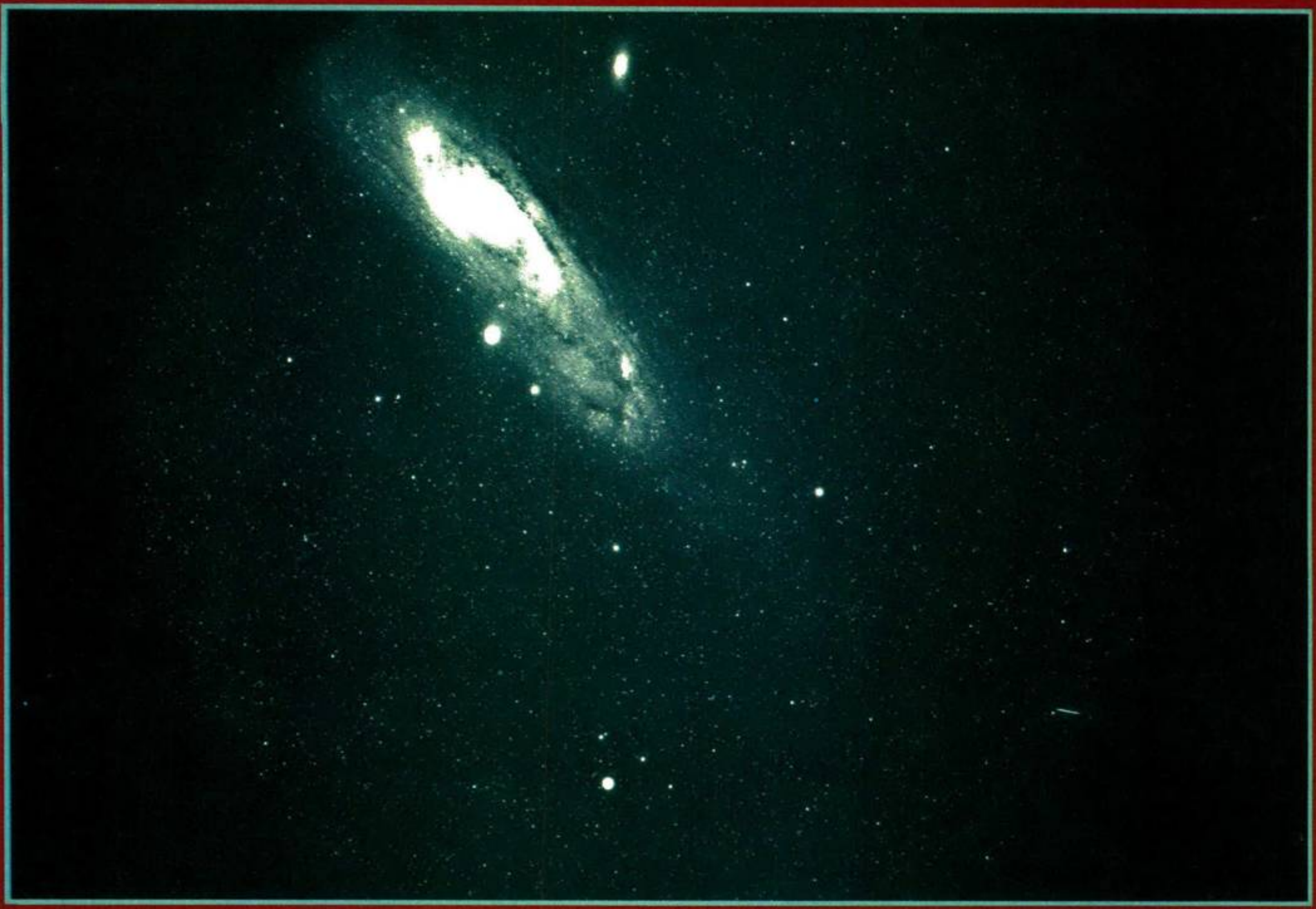
Top: During mid-October, Halley lay near the large emission nebula NGC-2174/5 in Orion. When this photo was made on the 13th, Halley shone at about 10th magnitude and covered some 2' of sky. Photo by Martin C. Germano using an 8-inch f/5 Newtonian, 103a-F film, and a 30-minute exposure. *Right:* In Milan, Italy, Marco Milani photographed the comet's encounter on October 11. He used a 10-inch f/4.8 Newtonian and 3M 1000 film for this 30-minute exposure. *Above:* Halley photographed on October 17 with a 12.5-inch f/5.6 Newtonian, hypered TP 2415 film, and an 8-minute exposure. Photo by Daniel R. Marcus and Bill Smith. *Left:* Halley photographed on November 8 with a 5.5-inch f/3.64 Schmidt-Newtonian, hypered TP 2415 film, and a 6-minute exposure. Photo by Daniel R. Marcus and Bill Smith.

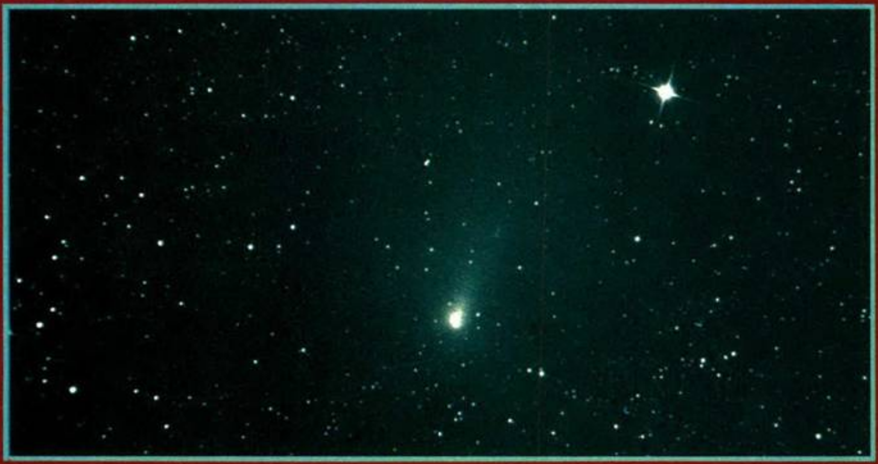


As backyard astronomers scrambled to observe and photograph Halley at every opportunity, professional astronomers were busy analyzing the comet. *Left:* On August 23, Hyron Spinrad of the University of California at Berkeley recorded this false-color CCD image of Halley with the 3-meter reflector at Lick Observatory. As early as late August, the coma (shown in red) had become noticeably egg-shaped, indicating a developing tail. *Right:* Astronomers Bruce Goldberg of JPL, Ian Halliday of the Herzberg Institute of Astrophysics, and Chris Aikman of the Dominion Astrophysical Observatory made this false-color image of Halley on September 11. They used a CCD camera on the 3.6-meter Canada-France-Hawaii telescope at Mauna Kea, Hawaii. *Right inset:* On September 10, Steven Majewski, a graduate student at the University of Chicago, used the 4-meter Mayall telescope at Kitt Peak to capture this false-color image of Halley. *Middle inset:* Professionals even recorded Comet Halley from downtown Washington, D.C. This 5-minute exposure on Tri-X film was made on October 26 with the U.S. Naval Observatory's 24-inch reflector. Photo by Theodore J. Rafferty. *Left inset:* This first image of Halley taken from space was made by a camera aboard the International Ultraviolet Explorer satellite on September 10. NASA photo. *Below:* Astronomer Arturo Gomez recorded Halley and emission nebula NGC-2174 on October 11 using Cerro Tololo's Curtis Schmidt telescope; he used a 15-minute exposure on an unfiltered blue plate.



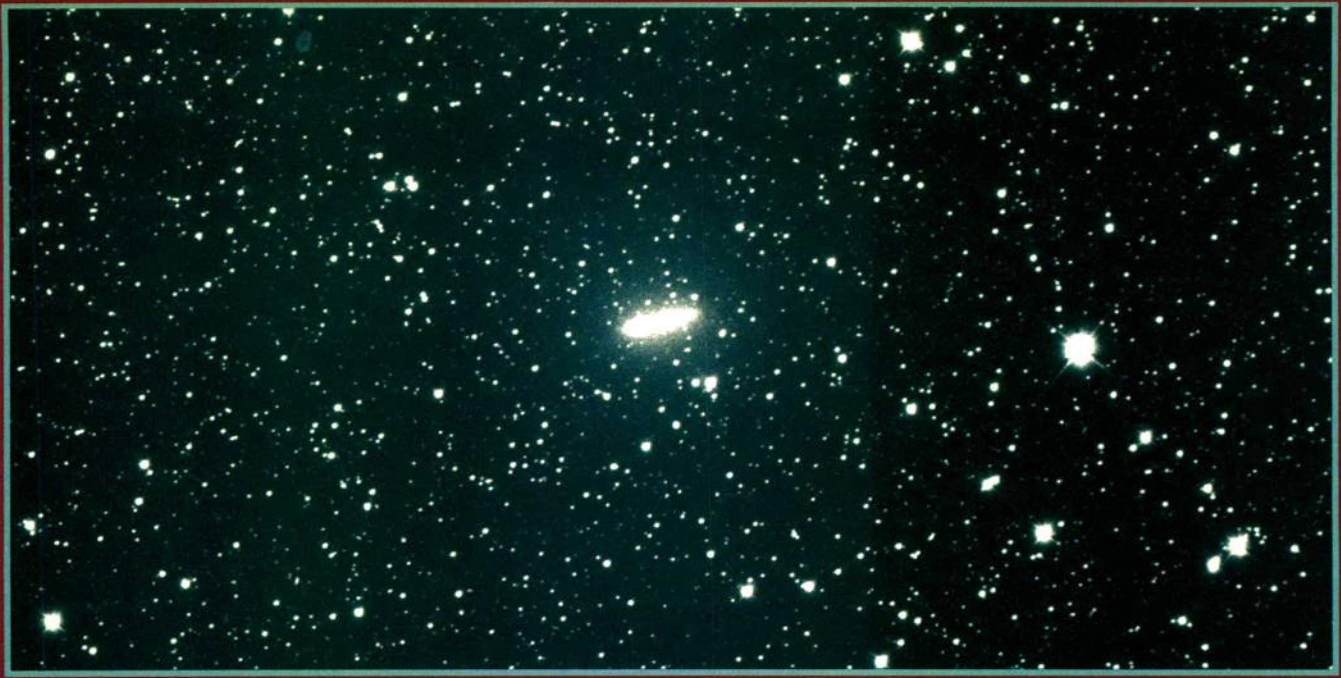






During summer and fall 1985 as Halley was brightening, three other comets became visible to backyard observers. *Above*: Comet Thiele, discovered on October 9 at the Max Planck Institute in Germany, brightened to 8th magnitude in early November. Jim Riffle recorded Thiele when it passed near M-31, the Andromeda galaxy, on November 7. The photo is a 30-minute exposure on 103a-F film, made with a 12-inch f/5 Astro Mak camera. *Left:* Comet Giacobini-Zinner, a bright binocular object all summer long, faded to obscurity by year's end. This photo was made on September 16 by Martin C. Germano, who used an 8-inch f/5 Newtonian, 103a-F film, and a 10-minute exposure. *Bottom left:* This photo, made with a 12-inch f/5 Astro Mak camera and hypered Konica SR 1600 film, shows 10 minutes' worth of Thiele's motion. Photo by Jim Riffle. *Bottom right:* Comet Hartley-Good, discovered early in September by two Australians, rose quickly to brighter than 7th magnitude. Photo by Chris Schur using a 16-inch f/4.4 Newtonian, hypered Konica SR 1600 film, and a 15-minute exposure.

Right: On October 13, Comet Halley still appeared insignificant in the rich surrounding starfield. Another month brightened it to naked-eye visibility at magnitude 6.5. Photo by Hal Jandorf using a 5.5-inch f/3.64 Schmidt-Newtonian, 3M 1000 film, and a 10-minute exposure. *Inset:* Halley photographed on October 15 using a 4-inch f/2.64 Schmidt camera, hypered TP 2415 film, and a 35-minute exposure. Photo by Paul Roques.



Far left: **By October 19, Halley shone at 8th magnitude and had grown considerably larger since September. During mid-October, Halley became readily accessible to binocular and telescope owners everywhere, even under suburban skies. Photo by Kim Zussman using an 11-inch f/6.5 SCT, 3M 1000 film, and a 25-minute exposure.** ***Top:*** **Comet Halley four nights later, on October 23, showing 105 minutes' worth of motion. Photo by Al Lilge using a 12.5-inch f/8 Ritchey-Cretien and 098-04 film.** ***Bottom:*** **Tom Martinez, Tom Ruisinger, and other members of the Astronomical Society of Kansas City recorded this image of Halley (shown between tick marks) on August 25 using a 29-inch f/4.5 telescope and an RCA Vidicon camera.**

Continued from page 38

across, making it a routinely visible naked-eye object from a dark, moonless site.

Will this unexpectedly delightful activity continue? Will Halley perhaps shine two or three or even four magnitudes brighter than astronomers first thought? Will it become a truly impressive, bright naked-eye comet by March or April? Before getting our hopes up too far, remember that comets are unpredictable creatures; they behave just about any way they want. Some feel that the October and November 1985 brightening may have been only temporary; at press time we don't yet know. But at least Halley's Comet seems to be doing its best not to let us down.

— David J. Eicher

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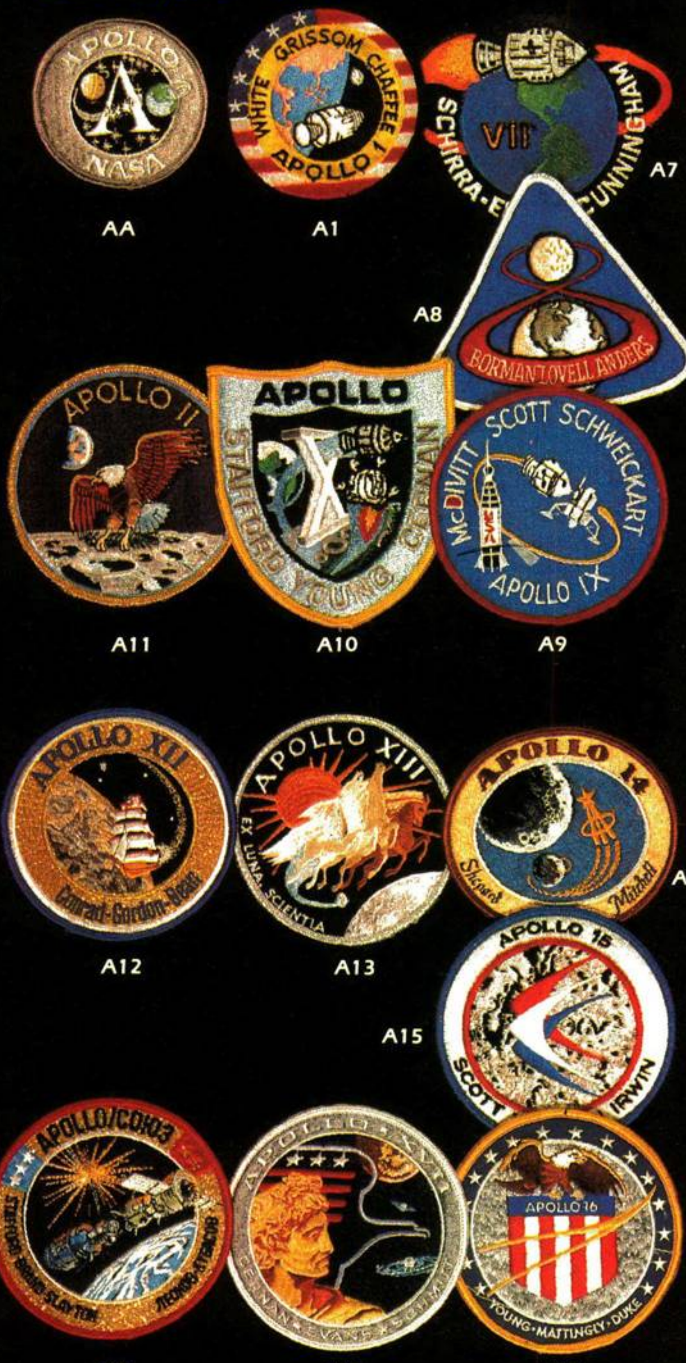
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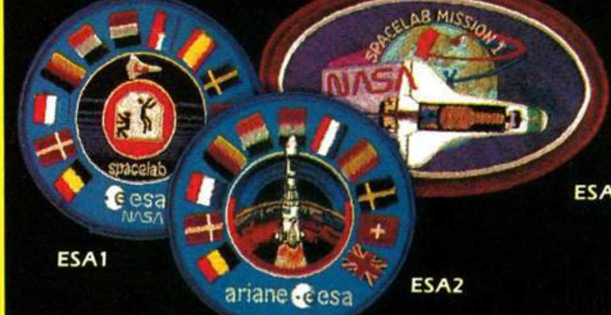
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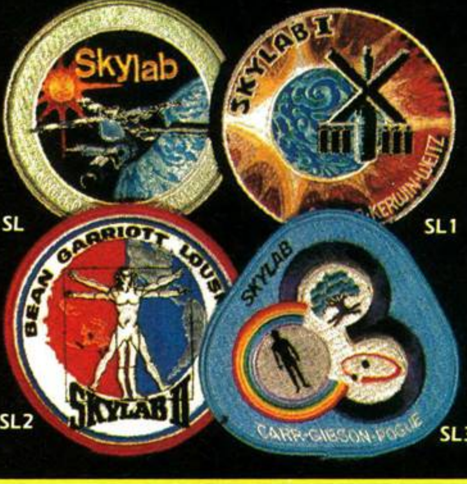
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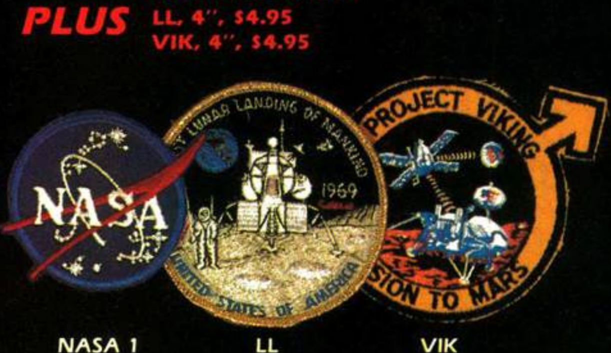
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ASTRONOMY
Reviews

With Halley's Comet hidden in the glare of the Sun this month, what better time to take a look at the recent crop of Halley books? (See Astronomy Reviews, October 1985 issue for additional Halley book reviews.)

The Mystery of Comets (276 pages, hardcover; Smithsonian Institution Press, Washington, DC 20560) is by "Mr. Comet" himself — Fred L. Whipple, the originator of the current dirty-snowball model for comets. The book is part of the "Smithsonian Library of the Solar System" series. Whipple explores the story of comets from early times to the present and gives the general reader a solid grounding in how comets work. He briefly discusses cometary "pre-history" (before Newton) and then devotes the remaining three-fourths of his book to the period since about 1750. Whipple includes much lore and many inside glimpses of how astronomers study comets.

Halley & His Comet by Peter Lancaster-Brown (186 pages, hardcover, $12.95; Sterling Publishing, 2 Park Ave., New York, NY 10016) combines a biography of Edmond Halley with a history of cometary astronomy that focuses on a few of the returns of the comet now bearing Halley's name. Though the biography is less complete than Colin Ronan's or Angus Armitage's (both out of print, unfortunately, but often available in libraries), it offers a great deal of contemporary gossip about the man. In all, a very enjoyable read.

Donald K. Yeomans is an astronomer at the Jet Propulsion Laboratory; his book *Comet Halley; Fact & Folly* (46 pages, hardcover, $30; Gold Stein Press, P.O. Box 12280, Santa Ana, CA 92712) takes the award for the most intriguing Halley book I've ever seen. If $30 sounds steep for 46 pages, there's a reason: the book measures about 2 by 2¾ inches, is handbound, and only 350 numbered copies were made. (For $55, you can get one of the 26 lettered copies, each with hand-colored title pages and signed by the author, the printer, and the binder.) What do you get for your money? A handsome little volume that contains seven well-written chapters with titles like "Comet Halley and Battle of Hastings," "Newton, Halley, and the Celestial Nature of Comets," and "Comet Halley is Coming." The text certainly hasn't room for a lot of information, but so what? Either you like cute little books or you don't. If you're like me, you'll treasure this as a delightful souvenir.

Yeomans has also teamed up with science writer Mark Littmann to author *Comet Halley; Once in a Lifetime* (175 pages, hardcover, $19.95; paperback, $10.95; American Chemical Society, 1155 16th St. N.W., Washington, DC 20036). This work explains comets and Comet Halley for the general reader in much more detail and is packed with illustrations culled from Yeomans' collection of old astronomy books.

"Get ready for the greatest show on Earth!" trumpets the cover of Asimov's *Guide to Halley's Comet* (118 pages, paperback, $5.95; Dell Publishing Co., 1 Dag Hammarskjold Plaza, New York, NY 10017). Actually, the book is a straightforward discussion of how our image of comets has slowly changed from being bad omens that frightened the superstitious to objects offering clues to the early history of the solar system. Although it has many period illustrations from past returns of Halley and other comets, the book, in fact, tells you nothing about where or how to observe Halley's Comet this time around!

Viewing directions are not lacking in *The Arrival of Halley's Comet* by Paul Doherty (32 pages, paperback, $8.95; Barron's, 113 Crossways Park Dr., Woodbury, NY 11797). Doherty's book contains a slight but effective text that briefly describes what a comet is and where it comes from along with a summary of the past two returns of Comet Halley. Five pages cover the 1985/86 return. There are also chapters on the space probes headed for Halley, and the relation of meteor streams to comets in general and Halley's in particular. The book includes a folded star chart with Halley's celestial path highlighted in phosphorescent ink.

The Return of Halley's Comet is by Patrick Moore and John Mason (121 pages, paperback, $6.95; Warner Books, 75 Rockefeller Plaza, New York, NY 10019). The book covers the history and the basic science of comets quite well, though general readers (i.e., those with little or no exposure to astronomy) will probably find places where the text goes over their heads. Its detail makes the book one of the more interesting works for the already initiated.

No astronomy teacher will let the comet pass by without devoting some time to it. *Halley's Comet For Classrooms* by William Glenn (16 pages, paperback, $1.50; National Science Teachers Association, 1742 Connecticuit Ave. N.W., Washington, DC 20009) and *The Return of the Comet* by Dennis Schatz (40 pages, paperback, $7.95; Pacific Science Center, 200 Second Ave. North, Seattle, WA 98109) are two lesson plan books that aim to supply educators with the basics. The Glenn booklet gives information on observing and photographing the comet and suggests three projects: visually measuring the length of the tail, the coma's diameter, and its brightness. Schatz's booklet, aimed at 9 to 14-year-olds, is bright and has more graphic appeal. Among other things, it asks the reader to draw pin-and-string comet orbits, make a Halley time capsule, assemble a comet movie "flip book," and fill in a Halley orbit time chart ("What do you think will be happening to you in 2007?").

The Complete Comet Watcher's Guide by Alan Marcus and Gary Crandall (88 pages, paperback, $4.95; Outer Ring Publishing, 500 Promontory Dr. West, Newport Beach, CA 92660) has the wonderful subtitle, "How to Survive the Return of Halley's Comet Without Having to Sacrifice a Virgin." It is a thin but zany concoction of put-ons, bad jokes, and terrible puns unheard-of since those crazy star parties of last summer. (Sample: definition of "milky way" — 1. The name given by the ancients to the band of starlight that circles the sky. 2. A popular candy bar subsidized by the American Dental Association.) Unless your sense of humor has gone hopelessly highbrow, you'll find lots in here to make you chuckle.

Monte Roberts' *Capture a Comet* (222 pages, paperback, $12.95; Aurorae Publishing Co., P.O. Box 13975, Denver, CO 80201-3975) concentrates largely on photographing the comet. About a third of the book is on comet basics, but the rest gets down to the fundamentals of astrophotography. The author discusses mountings, guiding, cameras, films, lenses and sky coverage, and so on. The book concludes with a glossary, bibliography, and an index.

Comet Fever by Donald Gropman (189 pages, paperback, $7.95; Simon & Schuster, 1230 Avenue of the Americas, New York, NY 10020) focuses on the popular reaction to past comets and Halley's. After a short explanation of comet basics, Gropman delves into the sometimes lurid, sometimes pathetic accounts in the popular media from the 1910 return. It's a good browse through hysteria and hype of the Edwardian era.

A perfect complement to Gropman's book is Roberta Etter and Stuart Schneider's *Halley's Comet; Memories of 1910* (96 pages, hardcover, $19.95; Abbeville Press, 505 Park Ave., New York, NY 10022). Almost devoid of text, this striking book is really a picture album of newspaper clippings, matchboxes, advertisements, postcards (yes, even some naughty French ones!), jewelry, and other memorabilia from yesteryear. It's as if your grandparents systematically collected Halleyana, pasted it all in a scrapbook, and now, years later, you've found the book at the bottom of a dusty old trunk in the attic. You sit down and begin to flip through it. Here's a 15 cent ticket for a lecture on "Haley's" Comet by Prof. D.W. Morehouse of Yale. And there's the comet fan that the folks who made Morse's Indian Root Pills were giving away. And here's the Boston American newspaper clipping that says the paper's Want Ads "will find anything, even a comet." And here's . . . . Well, you get the idea. Look no further if you want proof that books, like comets, are really time machines! *Robert Burnham.*

Rings: Discoveries from Galileo to Voyager
James Elliot and Richard Kerr
209 pages, hardcover, $17.95
MIT Press (1984)

"This is the story of scientific discovery. You will not find it in a textbook . . . . [It] is the seemingly 'unscientific' way that science sometimes makes progress. In the case of planetary rings, theory did not lead the way to observation and discovery — rather discovery led theory."

This theme ties an otherwise rather disjointed text into a unique whole. The book is written by James Elliot, one of the discoverers of Uranus' rings, and Richard Kerr, a staff writer for *Science*. The authors apparently could not decide who they were writing for. Parts of the text read much like a scientific paper, while other sections have a popular, first-person flavor.

Despite the book's stylistic incongruities, Elliot, like so many of the great explorers of our age, has such an obvious enthusiasm and love for his work that it shines through to make *Rings* harder to put down than any novel.

The first chapter is a breathtakingly immediate account of the discovery of Uranus' rings, complete with transcripts of the dialogue aboard the Kuiper Airborne Observatory as Elliot and his coworkers detect the rings while observing the planet's occultation of a star. Although cryptic and rather incomprehensible, the transcripts nonetheless capture the intense excitement as the scientists began to realize what they were seeing.

Following this opener is an interesting history of the discovery of Saturn's rings. The emphasis throughout lies on evidence that, for one reason or another, was ignored. For example, planetary scientists were very surprised when Voyager images showed that the old A, B, and C ring classification was far too simple; Saturn, it turned out, had zillions of rings. Why such surprise? Simple: everyone *knew* Saturn's rings had a relatively simple particulate structure dominated by a few gaps produced by orbital resonances with its moons.

Yet there had long been dissenters. John Westfall made observations in 1957 that showed "many rapid rises and falls in brightness" as a star was slowly occulted by the rings. In the 1940s, Bernard Lyot at the Pic-du-Midi Observatory in the French Pyrenees produced drawings that look remarkably like Voyager's grooved phonograph record photographs of the rings. Even more impressive were the 1851 observations made by Charles Tuttle with a 6.3-inch refractor that reported the rings to be "minutely subdivided into a great number of narrow rings . . . not unlike a series of waves."

Saturn wasn't the only place where reality collided with scientific preconceptions. At Jupiter, clear evidence from the particles and fields experiments aboard Pioneer 10 and 11 — and the not-so-clear-evidence from their meteoroid detectors — were largely ignored because everyone *knew* that only Saturn had rings. Though both spacecraft sustained some meteoroid strikes near Jupiter's equatorial plane, the significance of these strikes was uncertain, and they did little to encourage the scientists to consider alternatives to the prevailing view.

At the same time, the particles experiments reported distinct dips in Jupiter's radiation environment, evidence that was much less ambiguous. But despite this, Jupiter's few ring advocates had to lobby fiercely to get a single narrow-angle photo and a single wide-angle photo included in Voyager's busy encounter schedule. The wide-angle photograph was hopelessly overexposed, but the famous narrow-angle shot caught the very edge of Jupiter's ring. Elliot and Kerr call it "The Lucky Shot."

Rings also looks at the latest theories on the three ring-bearing planets, particularly the growing realization that Saturn's rings may look more like Uranus' than the other way around; narrow rings seem to be the rule rather than the exception. Here again, first-person descriptions of Voyager's minute-by-minute discoveries at Saturn rival fiction.

Finally, the authors turn to the question of a possible ring for Neptune. They present occultation data (much of it is Elliot's own) that place an upper limit for any neptunian ring at a size and density close to Jupiter's ring. Then, in view of Neptune's rather odd satellite system with the retrograde and highly inclined orbit of its large satellite Triton, the authors conclude that a substantial ring system for Neptune is unlikely to be stable. The book doesn't, however, cover the recent and unexplained "partial" occultation data, which appear to show that a broken and incomplete neptunian ring does exist.

Rings is a book filled with the endless fascination of discovery. I rate it well worth the modest amount of effort required to read it. *Donald F. Robertson.*

The Impact of Science on Society
James Burke, Jules Bergman, and
Isaac Asimov
96 pages, paperback, $4.50
NASA (1985)

To celebrate its 25th anniversary, NASA gathered a historian (Burke), a newsman (Bergman), and a science writer (Asimov) to give public lectures on the title topic. Their edited speeches are followed by a selection of questions from the audience and replies by the speaker. Order as NASA SP-482 from the U.S. Government Printing Office, Washington, DC 20402.

From Sputnik to Space Shuttle
Iain Nicholson
224 pages, paperback, $9.95
Dodd, Mead (1985)

Subtitled "The Complete Story of Space Flight," this is the American reprint of a book published in Britain in 1982. Nicholson begins with the launch of Sputnik, then backs up to consider "ways and means," giving a brief history of how rockets work. Then comes the main coverage, dealing essentially with the period from 1960 onward, of which about half is devoted to unmanned spaceflight.

Solar Neutrinos and Neutrino Astronomy
M.L. Cherry, K. Lande, and
W.A. Fowler, eds.
322 pages, hardcover, no price given
American Institute of Physics (1985)

This collection, intended for the professional astrophysicist, reprints the papers given at the Homestake Mining Company Conference in 1984. Most of the papers deal with the solar neutrino problem; of them, half are on the physics of emission, half are on instrumentation. The last four papers in the book deal with neutrino astronomy itself.

Physics and Astrophysics; A Selection of Key Problems
V.L. Ginzburg
125 pages, paperback, $12.50
Pergamon Press (1985)

Translated from the third Russian edition (1979), this work sets out to explain 24 current "problems" and give the author's ideas on them. These problems include the behavior of matter in ultra-high magnetic fields, the interaction of particles at high and extremely high energies, gravitational waves, quasars and active galactic nuclei, neutrino astronomy, the physics of black holes, and so on. Although little mathematics is used, readers without a good grounding in astronomy or physics will find the going difficult.

A l'Affut des Etoiles
Pierre Bourge and Jean Lacroux
307 pages, softcover, no price given
Dunod (1984)

A manual for amateur astronomers containing information on the planets, stars, deep-sky objects, telescopes, observing, and astrophotography — in French.

Active Galactic Nuclei
J.E. Dyson, ed.
383 pages, softcover, $26
Manchester University Press (1985)

This volume contains the proceedings from a conference on active galaxies held at Manchester University in 1984.

The Space Transportation Systems Reference
Christopher Coggin, ed.
About 300 pages, hardcover, $24.95
Apogee Books (1984)
[Publisher's address: 37 Hawthorne Ave., Sault Ste. Marie, Ontario, Canada]

Designed to look like the operating manual for the Shuttle, this book reprints a lot of NASA material. It includes fold-out diagrams of the control panels which show the positions and labels on every switch, toggle, button, and blinking light the craft has. It also inventories the lockers, right down to showing where they stash the aspirin and toothpaste.

Wind As a Geological Process
Ronald Greeley and James D. Iversen
333 pages, hardcover, $59.50
Cambridge University Press (1985)

The significance of eolian processes in sculpting landscapes has been well-established since 1941, when Ralph Bagnold's classic study on the physics of blown sand was first published. In this book, the authors (a planetologist and an engineer) examine the roles played by wind erosion on Earth, Mars, Venus, and

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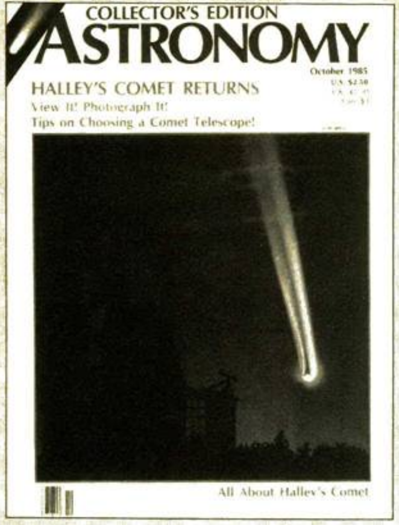

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Titan. Although the work on Titan is necessarily theoretical (no space probe has yet seen its surface), the sections that deal with the other three planetary bodies rest on directly-observable phenomena. The authors assume the reader is familiar with college-level planetary science.

The Story of the Earth
Peter Cattermole and Patrick Moore
224 pages, hardcover, $24.95
Cambridge University Press (1985)

Intended for a popular readership, this book surveys all of Earth history, focusing first on the gross properties of our planet and its astronomical context, and then on the techniques used to study it. The chapters that follow deal sequentially with the major epochs in geological history, ending with the Holocene — Earth now.

Spacefarers of the '80s and '90s
Alcestis R. Oberg
238 pages, hardcover, $24.95
Columbia University Press (1985)

Subtitled "The Next Thousand People in Space," this book takes a look at the evolving U.S. space program and what jobs it will offer people who want to live and work (at least temporarily) in space. These "will be the ultimate civilizers of the space frontier." The book also examines the military space program.

From Spacelab to Space Station
H. Stoewer and Peter M. Bainum, eds.
259 pages, paperback, $40;
hardcover, $50
American Astronautical Society (1985)

In October 1984, a symposium was held in Hamburg, West Germany, to explore ways to adapt technology and systems from the already-successful international effort, Spacelab, to the Space Station, which is still in the planning stages. Three chapters detail Spacelab flight results and 10 others propose designs for various systems of the Space Station.

Fire and Ice; a History of Comets in Art
Roberta J.M. Olson
134 pages, paperback, $14.95;
hardcover, $24.95
Walker and Company (1985)

Olson, a professor of art history at Wheaton College, was the first to note in print that Giotto's now-famous "Star of Bethlehem" in the chapel frescos was probably a portrait of Comet Halley. This book, which contains 118 plates, explores many of the ways comets — not just Halley's — have been portrayed, both to scientific ends as well as artistic ones.

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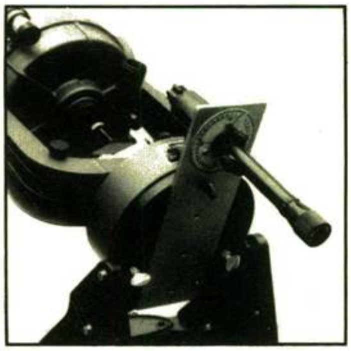

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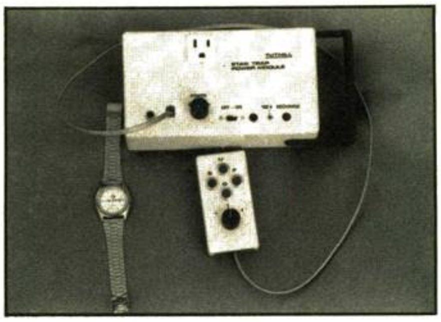

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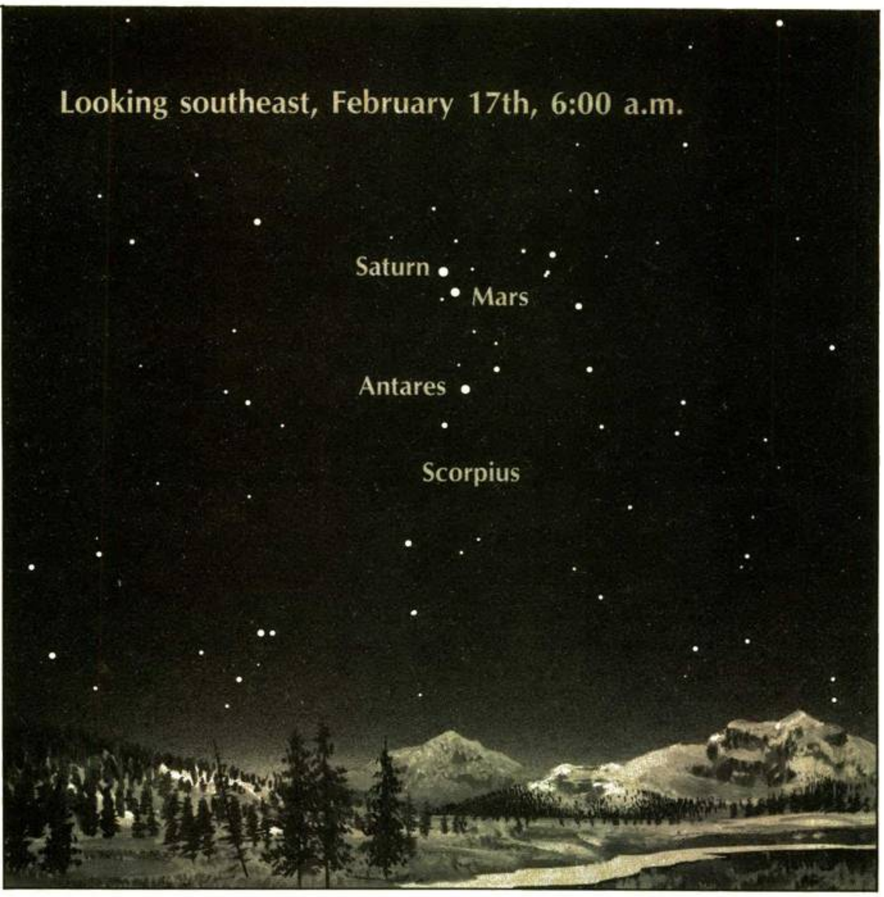
Halley Reaches Perihelion

by Fred Schaaf


Looking southeast, February 17th, 6:00 a.m.
Saturn
Mars
Antares
Scorpius

The Wanderers

With the pre-perihelion performance of **Halley's Comet** over, we have just one more month to wait to see how spectacular the comet will be when it swings out from behind the Sun. Solar conjunction is on February 5th and perihelion is on the 9th, but the first naked-eye sighting of the comet's tail may occur before the end of February. Look for a diffuse glow low in the southeast before morning twilight brightens during the last week of February.

While you plan for the exciting weeks ahead, there are some planetary sights to see now.

Pale-orange **Mars** is moving eastward through the head of Scorpius. It passes 16 arc-minutes south of 2nd-magnitude Beta (β) Scorpii on the morning of February 7th. The 0.9-magnitude planet then moves onward toward golden-hued **Saturn**. At magnitude 0.5, Saturn lies 6½° north of Antares on the 9th. (Two more Saturn-Antares conjunctions occur in 1986, but this one is the closest.)

Comparing their motions relative to Antares, Saturn hardly moves while Mars hustles along. Mars passes about 5° north of Antares on the 17th; notice how similar their colors are. By the 18th, Mars will have passed south of Saturn, missing it by 1° 16′.

For several months the sole bright planet in the evening sky has been **Jupiter**, but it is now lost from view in evening twilight. Jupiter sets with the Sun by mid-month and reaches superior conjunction on the 18th. **Venus** is slowly gaining altitude in the evening sky but won't become prominent as an "evening star" until late March.

Mercury was at superior conjunction on the last day of January (EST) but is now moving quickly; on February 28th, the planet is at greatest eastern elongation, 18° from the Sun. By mid-February, sharp-eyed observers can glimpse Mercury very low in the west after sunset as it begins a favorable evening apparition.

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

The Starry Sky

February is the month of the Dog Stars. These are Sirius and Procyon, the chief luminaries of the Great Dog **Canis Major** and the Little Dog **Canis Minor**, respectively. These two constellations are often regarded as Orion's hounds that follow him in his nightly journey across the sky.

On February evenings, **Orion** has passed the meridian, but the two canine constellations are at their highest. Blue-white Sirius is often regarded as the heart of Canis Major, but sometimes it is seen as its head or eye. Sirius, the primary Dog Star, is the source of the phrase "dog days." The ancient belief was that Sirius, shining in the daytime summer sky, added its heat to that of the Sun.

If you observe under a dark sky, try to see the star cluster M-41 with your naked eye. It resembles a blurry patch just 5° south of Sirius. Other open clusters within naked-eye range include M-35 at the northern feet of Gemini and NGC-2244, which is surrounded by the elusive and faint Rosette Nebula in northern Monoceros.

In March 1981, Randall Beachler and Joseph Manacci traveled from Ohio to Thompson, Manitoba to photograph aurorae. They took this shot with a 50mm f/1.8 lens, Ektachrome 200 film, and about a 15-second exposure. The stars of Auriga are at left center.

Monoceros the Unicorn and **Puppis** the Poopdeck (of the ship Argo) are neighbors of Canis Major. They are interesting to naked-eye observers because the winter Milky Way runs through them. You'll need a dark, transparent sky to trace out this stretch of the Milky Way, though!

Monoceros and the Milky Way separate Sirius and Canis Major from Procyon and Canis Minor. Procyon, meaning "before the Dog," is so called because it rises a little before Sirius, the more famous Dog Star. Procyon rises earlier, even though the star is almost one hour of right ascension east of Sirius; this occurs because Procyon is located at a declination about 20° farther north. The declination difference also works in reverse: by early June, when Sirius has long since disappeared from the evening sky, Procyon still hovers above the Sun's afterglow.

For many observers, **Gemini** the Twins looms high overhead. Yet aside from Gemini's "twin" stars Castor and Pollux, the northern sky between Gemini and the Pole Star is one of the dimmest, most sparsely-starred in the entire heavens. The

February's Night Sky

Last Quarter
February 1
11:41 p.m. EST

New Moon
February 8
7:55 p.m. EST

First Quarter
February 16
2:55 p.m. EST

Full Moon
February 24
10:02 a.m. EST

1st Last Quarter Moon occurs at 11:41 p.m. EST.

4th The Moon is closest to Earth at 11:14 a.m. EST: 229,175 miles.

7th Mars passes just south of Beta (β) Scorpii in the predawn sky.

8th New Moon occurs at 7:55 p.m. EST.

9th Halley's Comet is at perihelion; Saturn passes 6° north of Antares in the morning sky.

15th Start looking for Mercury very low in the southwest after sunset. One of the year's best apparitions for the elusive inner planet occurs during the next three weeks.

16th First Quarter Moon occurs at 2:55 p.m. EST; it is farthest from Earth at 5:23 p.m. EST: 251,193 miles.

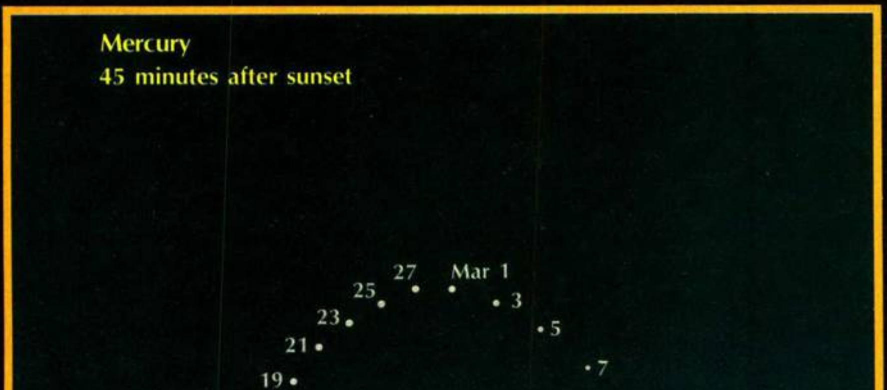
17th Mars passes about 5° north of Antares in the predawn sky and passes Saturn a few hours thereafter.

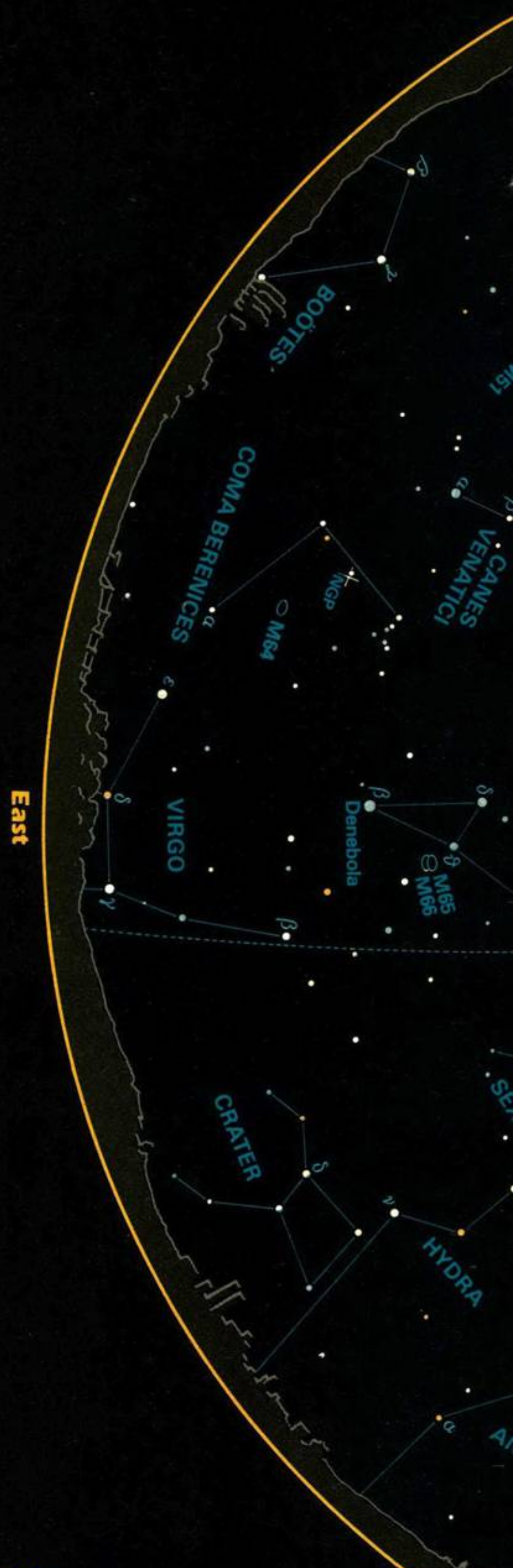
18th Jupiter is in conjunction with the Sun and shifts to the morning sky. Look for it low in the east before sunrise early next month.

24th Full Moon occurs at 10:02 a.m. EST.

25th Start looking for Halley low in the southeast as morning twilight begins, but you may not see it for a week or two.

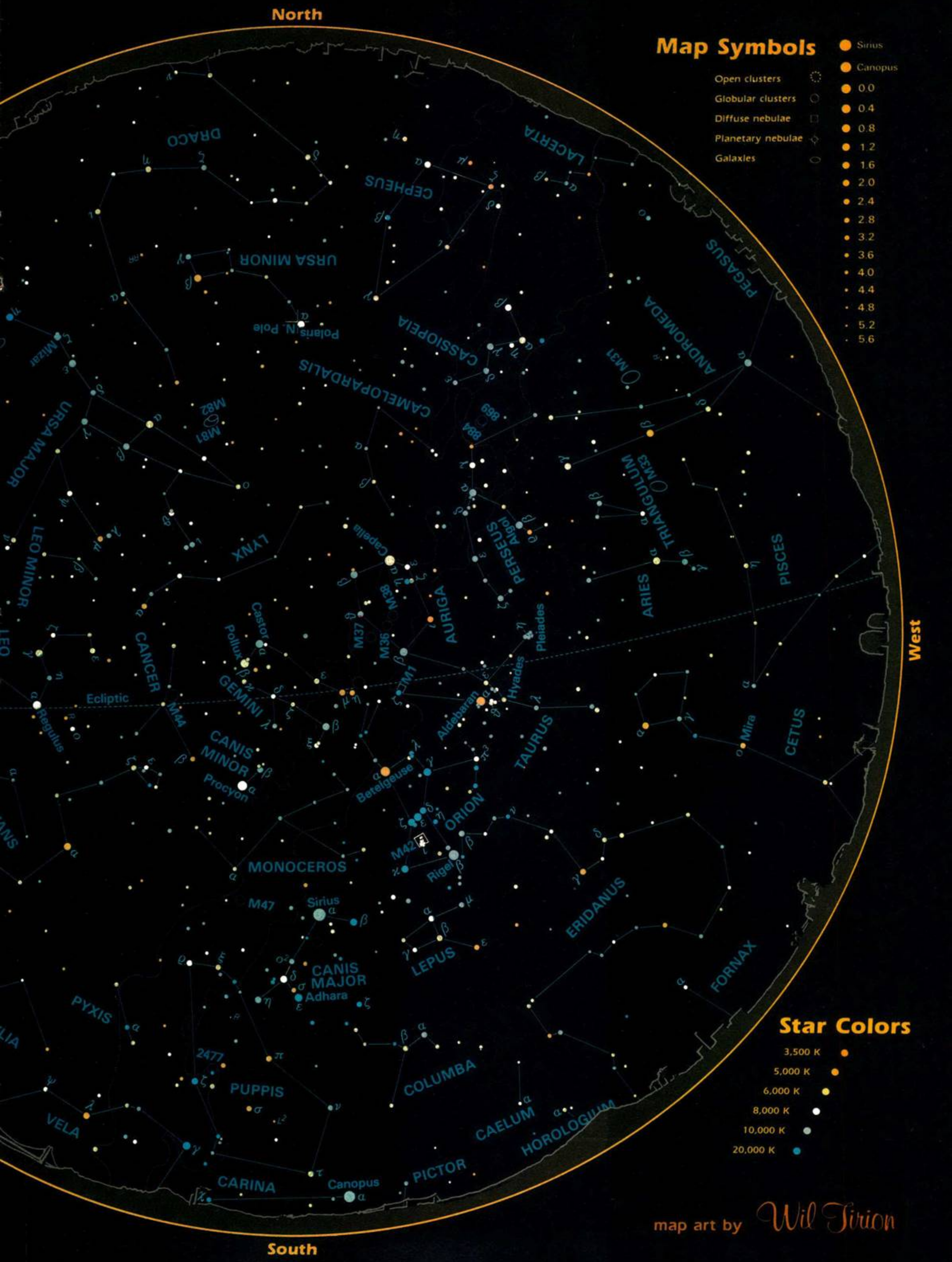
28th Mercury reaches greatest eastern elongation from the Sun in the evening sky. It will remain visible in the southwest after sunset through the first week of March.





The
Star Dome
shows how the
sky looks at:

10:00 p.m. on February 1st
9:00 p.m. on February 15th
8:00 p.m. on February 31st


North
South
West
Map Symbols
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies
Sirius
Canopus
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8
5.2
5.6
DRACO
CEPHEUS
LACERTA
URSA MINOR
Polaris
N. Pole
CASSIOPEIA
PEGASUS
ANDROMEDA
M31
CAMELOPARDALIS
M82
M81
869
884
URSA MAJOR
Mizar
TRIANGULUM
M33
PERSEUS
Algol
LEO MINOR
LYNX
Capella
ARIES
PISCES
AURIGA
M38
M37
M36
Castor
Pollux
CANCER
Pleiades
Hyades
M1
GEMINI
Ecliptic
LEO
Regulus
M44
Aldebaran
TAURUS
CANIS MINOR
Procyon
Betelgeuse
Mira
CETUS
ORION
MONOCEROS
M42
Rigel
ERIDANUS
M47
Sirius
LEPUS
CANIS MAJOR
Adhara
FORNAX
PYXIS
2477
PUPPIS
COLUMBA
VELA
CAELUM
HOROLOGIUM
CARINA
Canopus
PICTOR
Star Colors
3,500 K
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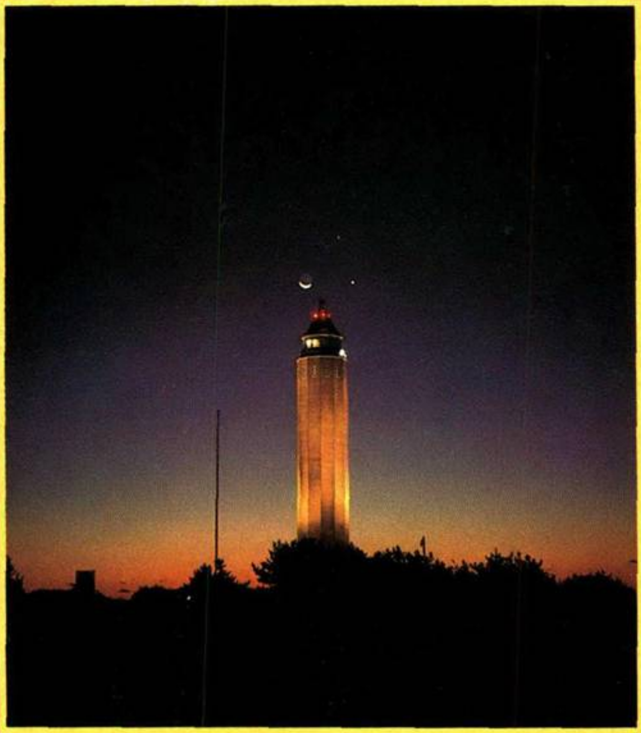
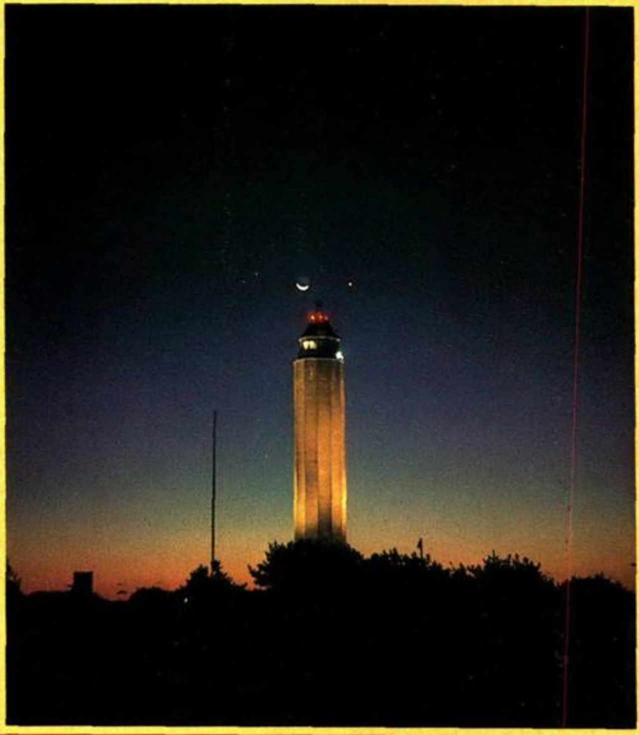
6,000 K
8,000 K
10,000 K
20,000 K

map art by Wil Tirion





Left top: Alpha and Beta Centauri and the Southern Cross arc over the lights of downtown Singapore in this photo by Christian Whitehouse. The picture was taken in May 1985 with Fujichrome 100 film, a 35mm f/3.5 lens, and a 1-minute exposure. Left bottom: This stereo pair shows the October 12, 1985 conjunction of the Moon, Venus, and Mars (toward upper right) over the Captree water tower on Fire Island, New York. Larry Landolfi used a Stereo Realist camera, Kodachrome 64 film, and a 4-second exposure at f/3.5.

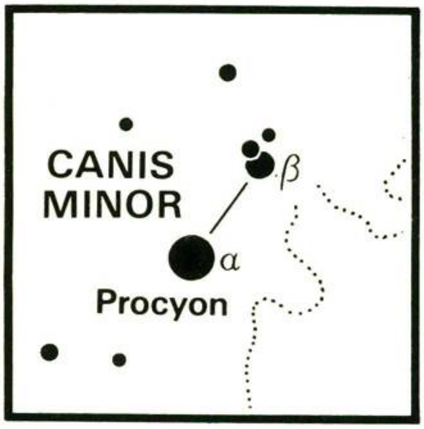
splendors of Orion, Gemini, the "Dogs," Taurus, and Auriga seem all the more blazing when you try to identify obscure Lynx and Camelopardalis.

Camelopardalis the Giraffe has no star as bright as 3rd magnitude; **Lynx** has only one. This is Alpha (α) Lyncis, which lies at the southeast end of the pattern not far to the northwest of **Leo** the Lion's head.

At the border between Gemini and Taurus, the Milky Way marks the position of the summer solstice. On the longest day of the year for the northern hemisphere, the Sun is surrounded by the invisible stars of Auriga, Taurus, Orion, and Gemini. Coincidentally, this is also where the equator of the Galaxy meets the ecliptic — the path that the Sun takes across the background stars. When you stare a few degrees east of Beta (β) Tauri, you are looking directly toward the galactic outskirts. Below the horizon behind you lies the galactic center in Sagittarius.

Skylore

Apart from Procyon, Canis Minor doesn't contain many interesting objects.

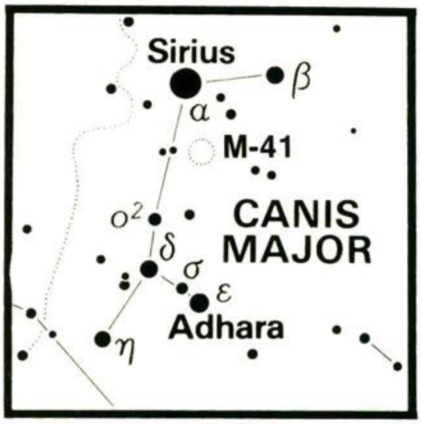


The Greeks knew the constellation (or perhaps just Procyon) simply as "before the Dog," since it rose just before Sirius. To the Romans, Procyon was the Northern Dog, the First Dog (first to rise), or the Sinister (meaning left-hand or eastern) Dog. According to R.H. Allen's book *Star Names*, Pliny claimed "the Dog Days" began not when Sirius first appeared before dawn (its heliacal rising) but when Procyon did.

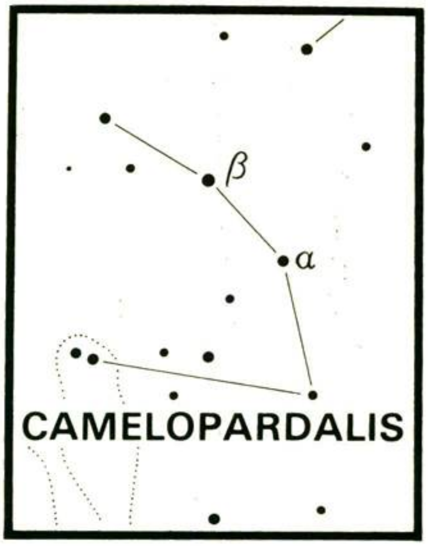
It is unknown how a second dog constellation came into being. Perhaps the idea of Sirius and Canis Major being dogs that follow the Hunter opened the door to making another bright star, just east of Orion, into an additional hound of his. An interesting oddity is that Canis Minor has been portrayed in some star atlases as a very different breed than Canis Major. The latter is usually drawn as a short-haired dog, but Canis Minor is often shaggy.

Canis Minor has been identified with a number of dogs from Greek mythology. One of these is Argus, the dog of Odysseus. When Odysseus finally returned to Ithaca, he discovered a domestic situation so dangerous that he had to enter in disguise. But even after two decades at sea, Odysseus was recognized by his dog. Old and much enfeebled, faithful Argus crawled to his master and expired, presumably happy, at his feet.

Another loyal pooch identified with Canis Minor is Maera, the dog of Icarius. Icarius had learned the secret of cultivating grapes for wine from the god Dionysus. But when Icarius served his wine to a group of shepherds, some of them became drunk and acted strangely. Their companions panicked and, believing Icarius had poisoned their friends, turned on Icarius and killed him.



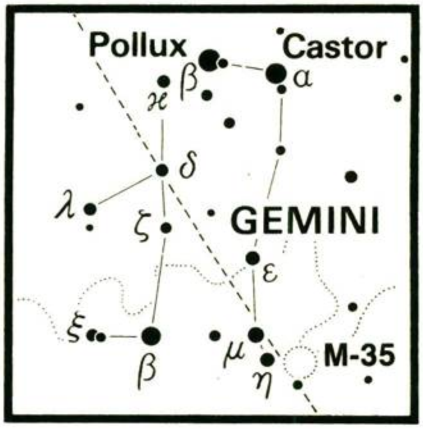
The killers buried Icarius secretly, but his daughter Erigone was led to the corpse by Maera. Maera howled in grief and scratched away enough dirt to reveal the terrible truth, whereupon poor Erigone hanged herself. But the gods took pity on them and raised loyal Maera to the heavens as Canis Minor and, in some accounts, also placed Icarius and Erigone among the stars as Bootes and Virgo. Appropriately, these two constellations are side by side, but Canis Minor — the faithful Maera — is quite far away.



The stars of Canis Minor have been associated with several lesser-known dogs in Greek mythology, too. One is the favorite dog of Helen who drowned in the Euripus Strait. Helen prayed to Zeus who granted her wish that the dog be set among the stars. Canis Minor might also be one of the hounds belonging to Actaeon, an unfortunate youth who inadvertently beheld Artemis when she was bathing. The outraged goddess turned Actaeon into a stag, who was then torn apart by his own dogs.

Some believe that Procyon was Kakkab Paldara, a figure on Mesopotamian cylinder seals. The name means "star of the crossing of the water dog" and may refer to Procyon's position on the edge of that celestial river, the Milky Way.

The Arabic name for Procyon is al Ghumaisa, which may mean "dim" (which it is relative to Sirius), or "the watery-eyed one," or "the weeping one." Why should Procyon be thought of as crying? A popular and delightful Arabic tale tells of Canopus (called Suhail), Sirius (al Shira), and Procyon (al Ghumaisa). The latter two were al Aliawat al Suhail, which means "the sisters of Canopus." Suhail married al Jauzah (a feminine Orion), but abandoned his bride and raced off south. Outraged by her brother's caddish manner, al Shira set off in pursuit of him and crossed the Milky Way, leaving poor Procyon behind. Bereft of her family, it's no wonder al Ghumaisa weeps!



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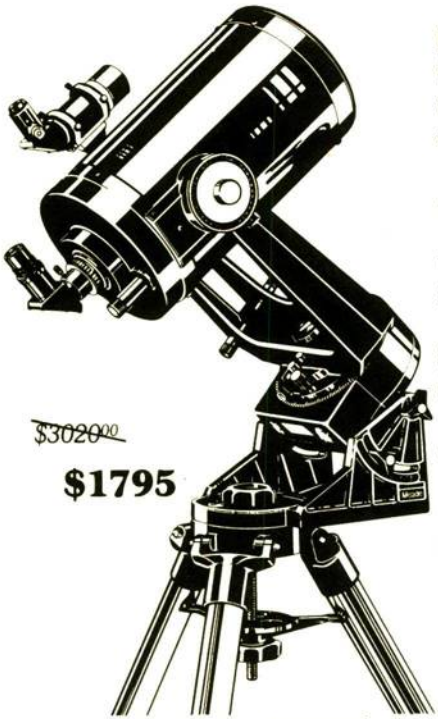

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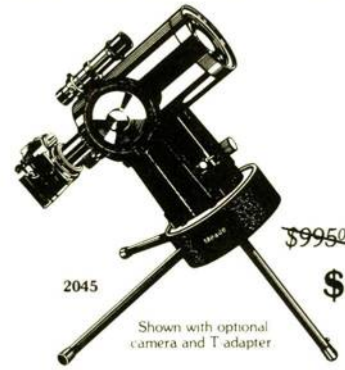
- 2080/LX2 with EMCG (enhanced mirror coatings group) for 12% more light transmission than standard coated optics $1599
- 2080/LX2 with high transmission coatings (10% more light than uncoated optics) $1549
- **Meade 2080/LX3, with MCSO**: The most sophisticated 8" Schmidt-Cassegrain available today! With multi-coated silver optics, deluxe worm gear quartz drive that operates from AC or DC, an 8 x 50mm illuminated polar reticle finderscope, two Research Grade eyepieces, piggyback camera mount, wedge, field tripod, lifetime warranty, and so much more! *$3020 list* . . . . **for $1795!**
- 2080/LX3 with high transmission coatings for 10% more light than uncoated optics $1695

Accessories for 2080/LX3

- $150 list #36 drive control box . . . . $\$99^{50}$
- $150 list #38 declination motor . . . . $\$99^{50}$
- $90 list dew cap . . . . $\$67^{50}$
- $220 list off-axis guider system . . . . $\$149^{00}$
- $120 list tube balance system . . . . $\$89^{50}$
- $30 list map light . . . . $\$22^{50}$
- $180 list 3" off-axis solar filter . . . . $\$134^{50}$
- $60 list setting circle lights . . . . $\$44^{50}$



2045

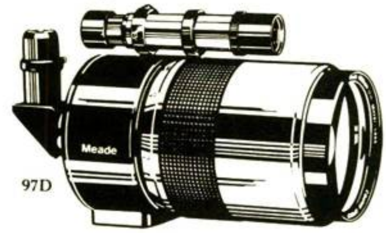
Shown with optional camera and T-adapter

~~$\$995^{00}$~~

$595

MEADE 4" SCHMIDT-CASSEGRAIN AND SPOTTING SCOPES

- **Meade 2045**: Compact 4" Schmidt-Cassegrain is telescope, spotting scope, and 1000mm telephoto lens — all in one! With motor drive, metal-clad case, 5 x 24mm finder, two eyepieces for 40x and 111x magnifications, coated optics, tabletop tripod, lifetime warranty, more! *$995 list* . . . . **for $595!**



97D

~~$650~~

$349

- **Meade 97D**: Compact Maksutov-Cassegrain spotting scope is the only reasonably-priced 3½" spotter to have high transmission coatings on its corrector lens to improve visual and photographic contrast. This 1000mm f/11 system comes with metal-clad case, 5 x 24mm finder, two eyepieces for 40x and 83x, coated optics, tripod adapter, helical focusing, lifetime warranty! *$650 list* . . . . **for $349!**
- **Meade 107D**: Compact 4" Mangin-Cassegrain is a fast 1000mm f/10 spotting scope and telephoto lens at a sensible price. With case, 5 x 24mm finder, two eyepieces for 40x and 111x, magnifications, micrometer focusing, coated optics, tripod adapter, lifetime warranty, more! *$750 list* . . . . . . **for $419!**

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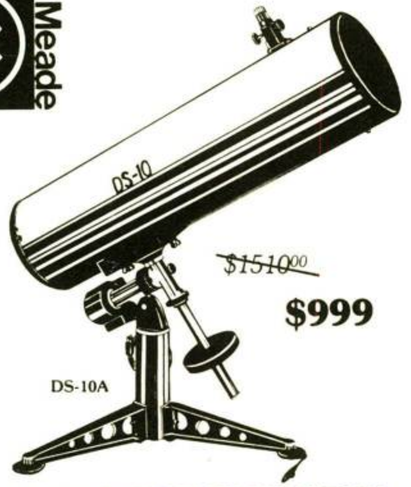

DS-10A

~~$\$1510^{00}$~~

$999

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Our Meade deep space reflectors include *every* accessory Meade supplies, plus *free freight* (except on the DS-16 and on DS-10 credit card orders). Just look at these bargains . . .

- **Meade DS-10A**: A 10" f/4.5 deep space reflector superb for dark sky viewing and astrophotography. With 25mm eyepiece, #680 focuser, pedestal mount, setting circles, worm gear motor drive, free freight, lifetime warranty. *$1510 list* . . . . **for $999!**
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- $140 #210PG guide scope w/rings . . . . . . $\$105^{00}$
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- $50 40 lb. counterweight substitution . . . . $\$37^{50}$
- $70 casters, set of 3 . . . . $\$52^{50}$
- $40 leveling screws, set of 3 . . . . $\$29^{95}$
- $30 2" eyepiece extension tube . . . . $\$22^{50}$
- $550 #48RS dual axis drive corrector . . . $\$389^{50}$
- $350 #300PG guide scope w/rings . . . . . . $\$262^{00}$
- DS-16, without motor drive . . . . $\$869^{00}$

All prices good through February 28, 1986, and limited to quantities on hand.

the price increases!

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- **Meade 826C**: Best all-around value 8" f/6 Newtonian reflector. Super for planetary/deep space visual and photographic work. With two eyepieces, 2" focuser with 1¼" adapter, 8 x 50mm finder, pedestal mount, leveling screws, latitude scale, latitude adjuster, setting circles, worm gear drive, free freight, lifetime warranty. *$1530 list* . . . . **for $999!**
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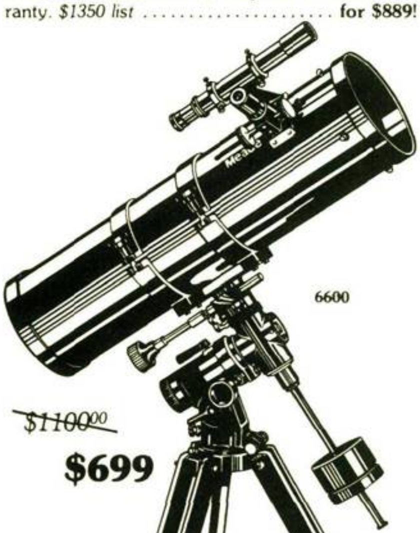

- **Meade 6600**: A compact 6" f/5 Newtonian reflector loaded with features for all-around great performance. With two eyepieces, 6 x 30mm finder, adjustable-height tripod mount with slow motion controls, metal tube assembly and dust cover, latitude adjuster, setting circles, free freight, lifetime warranty. *$1100 list* . . . . **for $699!**
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MEADE REFRACTORS

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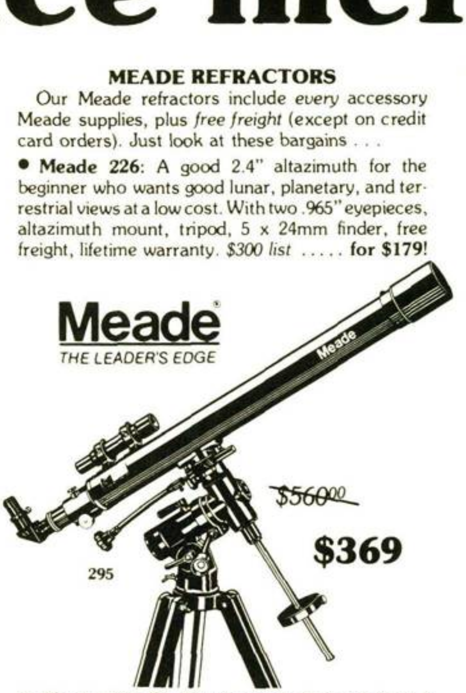

- **Meade 291**: Quality planetary observing from a bargain-priced 2.4" equatorial refractor. With two .965" eyepieces, equatorial mount and tripod, setting circles, slow motion controls, 6 x 30mm finder, free freight, lifetime warranty. *$460 list* . . . . . **for $319!**
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- **Meade 295**: An inexpensive 2.4" equatorial refractor with premium performance. With two .965" eyepieces, equatorial mount and tripod, setting circles, slow motion controls, 6 x 30mm finder, free freight, lifetime warranty. *$560 list* . . . . . **for $369!**
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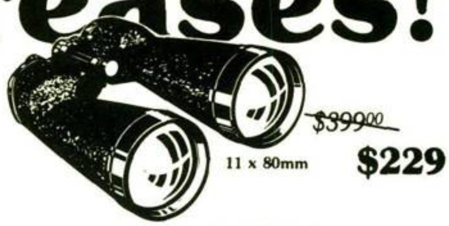
- $220 list #784 single axis quartz motor drive and drive corrector for the #295/320 . . . . $\$164^{50}$



MEADE BINOCULARS

For many people, the best view of Halley's Comet will be through Meade giant astronomical binoculars. Their 80mm objectives gather as much light as two 3.1" telescopes, for crisp, bright, wide field views of star clusters, nebulae, and galaxies — as well as comets. Each comes with lens caps, case, carrying straps, and a photo tripod adapter (tripod optional, but highly recommended). The 11 x 80 model is best for dark sky observing sites, while the 20 x 80 model is best for observing from the city or suburbs. Now with a lifetime warranty, too!

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- $419 20 x 80mm, 3.5° field . . . . **for $\$239^{00}$!**

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We have low prices on Meade accessories, too; accessories that fit Meade and Celestron Schmidt-Cassegrains, plus all brands of reflectors and refractors. And we don't make you buy a telescope to get those low prices, either, as some retailers do. Just look at these examples . . .

• $220 off-axis guider system (Includes guider body and illuminated reticle.)	$\$149^{00}$
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• $40 1¼" camera adapter	$\$29^{95}$
• $40 .965" camera adapter	$\$29^{95}$
• T-rings for above camera adapters.	
For Pentax S, Minolta, Nikon cameras	$\$9^{95}$
For Pentax K, Miranda, Exacta cameras	$\$10^{95}$
For Canon, Olympus cameras	$\$11^{95}$
• $120 1¼" illuminated reticle only	$\$79^{50}$
• $120 .965" illuminated reticle only	$\$79^{50}$
• $60 #122 2x Barlow	$\$44^{50}$
• $70 #123 3x Barlow	$\$52^{50}$
• $90 #124 2x or 3x Barlow	$\$67^{50}$
• $80 #127 2x-3x variable Barlow	$\$59^{50}$
• $60 #126 2x Barlow for 2045	$\$44^{50}$
• $40 Series 2 1¼" mod achro eyepiece (Specify 6, 9, 12, 25, or 40mm mod. achro.)	$\$29^{50}$
• $60 Series 2 1¼" 40mm EWF eyepiece	$\$44^{50}$
• $40 Series 2 .965" mod achro eyepiece (Specify 9, 12, 25, or 40mm mod achro.)	$\$29^{50}$
• $60 Series 2 1¼" ortho eyepiece (Specify 4, 6, 9, 12.5, 18, or 25mm ortho.)	$\$44^{50}$
• $60 Series 2 .965" ortho eyepiece (Specify 4, 6, 9, 12.5, 18, or 25mm ortho.)	$\$44^{50}$
• $90 Research Series 1¼" Erfle eyepiece (Specify 7, 12.5, 15.5, or 20mm Erfle.)	$\$67^{50}$
• $80 Research Series 1¼" ortho eyepiece (Specify 4, 7, 10.5, 16.8, or 28mm ortho.)	$\$59^{50}$
• $40 accessory shelf for 2080	$\$29^{95}$
• $90 dew cap for 2080	$\$67^{50}$
• $120 tube balance for 2080	$\$89^{50}$
• $120 tube balance for 2120	$\$89^{50}$
• $120 #43 single axis drive corrector	$\$84^{50}$
• $240 #41 single axis drive corrector	$\$179^{50}$
• $430 #46 dual axis drive corrector	$\$299^{50}$
• $430 #47M dual axis drive corrector	$\$299^{50}$
• $550 #48RS dual axis drive corrector	$\$389^{50}$
• $15 1¼" color filters (Specify whether #8, 11, 12, 21, 23A, 25A, 47, 58, 80A, or polarizing filter.)	$\$10^{95}$
• $80 #908 1¼" nebular filter	$\$59^{50}$
• $150 #911 nebular filter for visual back	$\$109^{50}$
• $40 piggyback for 2080	$\$29^{95}$
• $40 piggyback for 2120	$\$29^{95}$
• $150 wide field adapter system	$\$104^{50}$
• $60 1¼" porro prism	$\$44^{50}$

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Gazer's
Gazette

Galactic Clusters for Binoculars

by
James Haas

Unfortunately, a good many observers ignore binoculars as instruments for serious deep-sky observing. But even a pair of standard 7x50 binoculars is capable of showing subtle light from the brightest galaxies and nebulae, and they're highly portable to boot. Large binoculars — in the 10x70 to 20x80 class — may require a tripod for stability, but in return they reveal amazing detail in the brightest deep-sky objects.

Galactic, or open, star clusters are the best deep-sky objects for binoculars. Open clusters are groups of young stars encircling the plane of the Galaxy. Unlike dim galaxies and nebulae, they're generally large and bright and offer splendid views of clouds of stars in a binocular field. Finding them and observing their structure will not only show you many new objects for your binoculars, but will also make you a better observer.

Taurus: Two Bright Clusters

The winter sky contains dozens of open clusters scattered along the Milky Way. The constellation Taurus the Bull is a particularly good place to start since it contains two of the largest and brightest star groups in the entire sky.

The Hyades cluster is a huge V-shaped collection of stars that together with the Pleiades form most of the constellation. Its several dozen members, some as bright as 3rd magnitude, cover an enormous 5½° of sky — an area wide enough to accommodate eleven Full Moons placed end to end! The total magnitude of the Hyades is 0.5, but this does not include the magnitude 0.9 star Aldebaran (Alpha [α] Tauri) — a bright orange star seemingly within the cluster but actually located much closer to Earth.

Take your binoculars out on a clear dark night (along with a star atlas such as Tirion's *Sky Atlas 2000.0*) and scan the Hyades region. You'll see the bright, distinct "V" shape formed by Aldebaran, the double star Theta (θ) Tauri, Gamma (γ) Tauri, Delta (δ) Tauri, and Epsilon (ε) Tauri. Carefully look at each star and check its color relative to the others. In contrast to orangish Aldeberan, Theta^2 Tau — the brightest Hyades member — is a dazzling white. Gamma, Delta, and Epsilon are all deep yellow in color; the cluster's faint stars run the spectrum from bluish white to dark orange.

Just about 12° northwest of the Hyades is another brilliant cluster — the Pleiades, or Messier 45. This group contains about 100 stars in an area only one third as large as the Hyades, which causes it to appear far richer. Whereas the Hyades' stars have varied colors, the Pleiades' stars are young and predominantly bluish white. The brightest is Alcyone (Eta [η] Tauri) at magnitude 2.9. The group's most luminous stars take on the appearance of a dipper.

Before exploring the Pleiades with binoculars, take time to carefully view it with your unaided eyes. At least six of its stars are visible without optical aid and some observers claim to have seen a dozen or more. Now train your binoculars on the Pleiades: you'll see the distinctive dipper shape formed by Alcyone and the slightly dimmer stars Atlas, Merope, Electra, Celaeno, Taygeta, and Maia. Speckled amongst these 3rd-magnitude stars are numerous fainter pairs and rows of bluish white stars that fill more than a single binocular field.

Taurus holds several other impressive star groups, one of which is NGC-1647. This open cluster lies just 3° northeast of the center of the Hyades and contains some 200 stars in a 45′ diameter — just a Moon-and-a-half across. NGC-1647 shines with the light of a 6th-magnitude star and is easy to see in binoculars, appearing as a large clump of milky light dusted with tiny stars.

Perseus: The Double Cluster

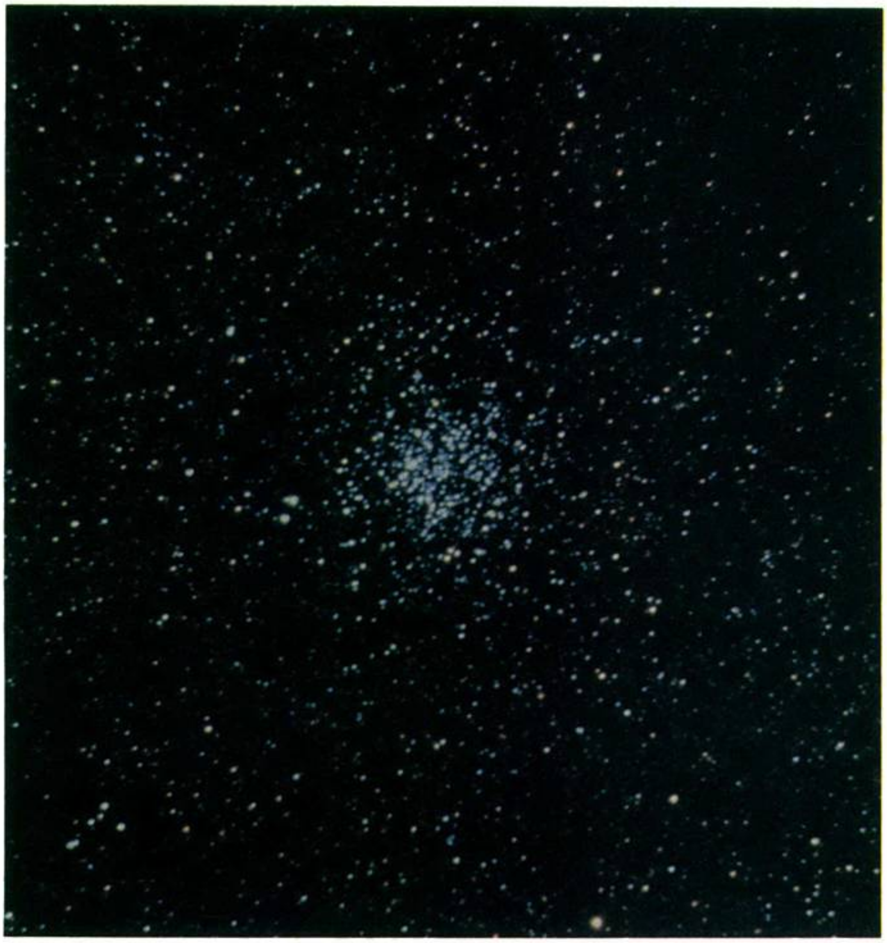
Adjacent to Taurus in the winter Milky Way is Perseus the Hero, an exceedingly bright constellation assembled in part from large star clusters. On your star atlas find the bright blotch of stars surrounding Alpha Persei near the center of Perseus. You'll note that there are many bright stars scattered around this area in no particularly organized fashion. Most of the bright stars in this region of sky belong to the Alpha Persei Moving cluster, an association of loosely-bound young stars circling the Galaxy. This group is also known as Melotte 20, named after the astronomer who catalogued large, loose associations of stars. Spanning some 3°, or six Moon diameters, Mel 20 contains Alpha Per (itself a magnitude 2.9 star) and about 50 other stars whose combined light gives the cluster a magnitude of 1.2.

Melotte 20 is not the most impressive of Perseus' star clusters, however. NGC-869 and NGC-884, two fairly compact but bright open clusters that are physically unconnected, lie less than a degree apart in that sky region. This has earned them the nickname the "Double cluster." Observers who train their binoculars on the field can see two clusters for the price of one. NGC-869, the westernmost cluster, contains some 200 stars and NGC-884 holds 150. Each covers about 30′ of sky and shines at approximately magnitude 4.5. The Double cluster is not only a grand binocular sight but it also serves as a test of sky darkness: If you can't see these clusters with the naked eye on a clear night, the sky transparency isn't good enough for observing faint objects.

Auriga: Messier's Bright Clusters

Auriga the Charioteer contains a large number of rather small star clusters. Three of them — M-36, M-37, and M-38 — are excellent binocular targets because of their relatively high total magnitude. M-36 and M-38 lie near the center of a large pentagon formed by Auriga's brightest stars; they're about 2° apart and fit together into a single low-power binocular field. M-36 appears as a grainy spot of haze some 12′ across; its 60 stars of 9th magnitude and fainter are normally

The Pleiades cluster in Taurus is one of the brightest groups of stars in the sky. Its "dipper" shape packs 100 stars into an area nearly 2° across. Photo by Philip J. Lambert using an 8-inch f/5 Newtonian, hypered Ektachrome 400 film, and a 40-minute exposure.



difficult to resolve with small binoculars. M-38 is nearly twice as large, holding 100 stars dimmer than 8th magnitude. Because it is loosely grouped, you may have more luck spotting individual stars within this cluster. Large binoculars — 10x70s or 20x80s — easily show the brightest stars in both M-36 and M-38.

Southeast of M-36 and M-38 alongside Auriga's giant pentagon is the brilliant cluster M-37. This is one of the richest open clusters in the sky; it compresses 150 stars of 9th magnitude and fainter in an area some 24′ across. Small binoculars show M-37 as a milky mass of light; 20x80s partially resolve the group, giving the impression of a shimmering uniform glow infested with tiny pinpoints of light.

Gemini: M-35 and Its Companion

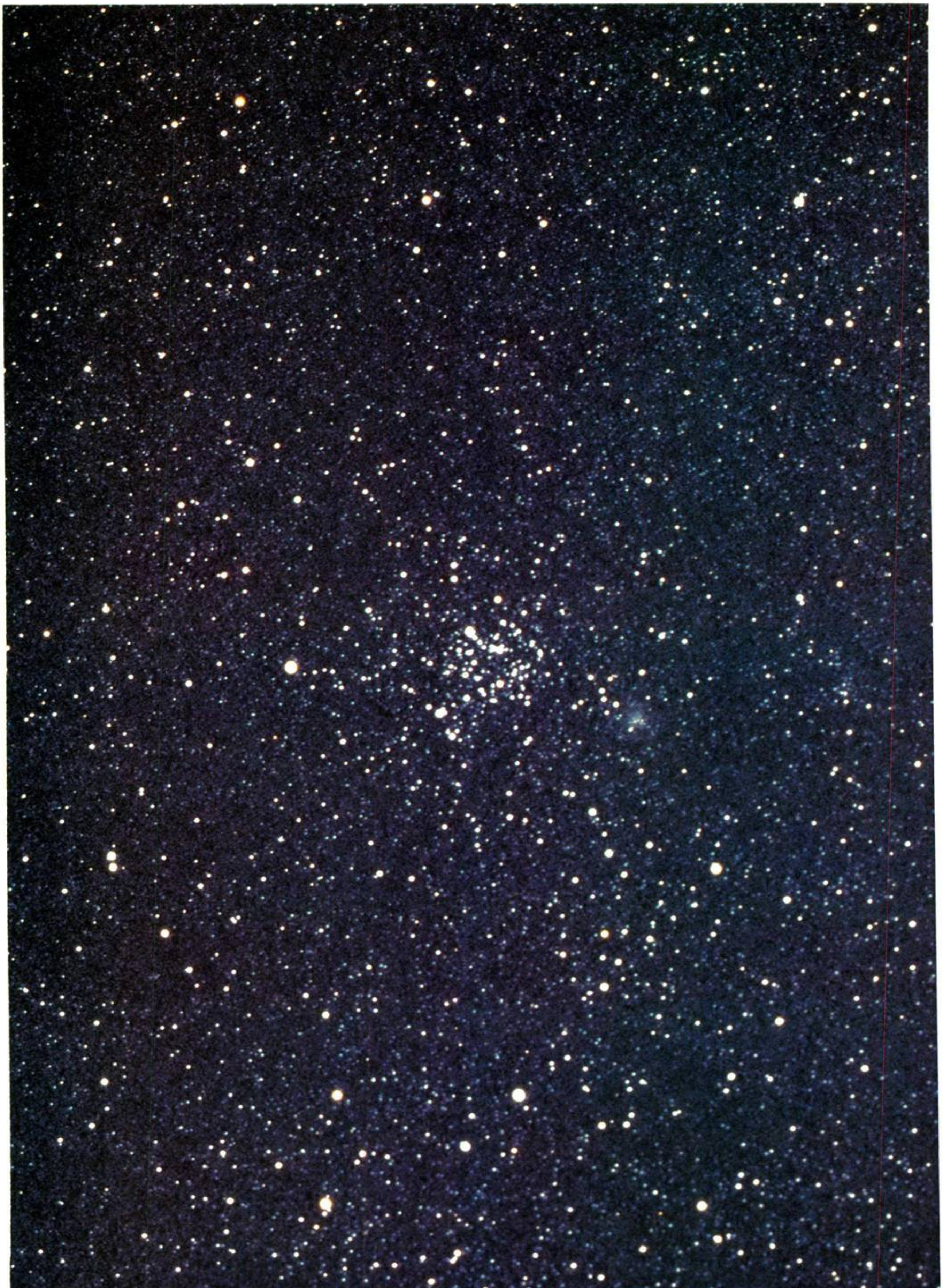
Nearby, Gemini the Twins contains another fine open cluster — M-35. This scattered group of at least 200 stars is easy to spot with the naked eye and very impressive in any size binoculars. It covers about the same amount of sky as the Moon and shines at 5th magnitude. Many of M-35's stars, those 8th magnitude and fainter, display strong colors and are arranged in attractive pairs and curving rows. The group's brightest member is a bluish white color, but many of the fainter stars are tawny yellow.

If you observe M-35 with a large pair of binoculars, you may see a faint, fuzzy spot of light on the cluster's southwest side. This is NGC-2158, another open cluster similar in structure but nearly six times farther away. This little companion is very difficult to resolve, appearing as a hazy spot at best, but it provides a good contrast to the widely scattered bright stars belonging to M-35 itself.

Puppis: Spot the Planetary?

Now look down the Milky Way toward the southern horizon where Puppis, the Poopdeck of the old ship Argo Navis, contains an entire cosmic ocean's worth of sparkling star clusters. The best of the lot, M-46 and M-47, reside just about 15° due east of Sirius, the brightest star in the sky. These two Messier clusters offer a tremendous contrast; they lie a mere 1½° apart yet have no physical connection and are completely different in nature. M-47 is a bright, loosely scattered collection of about 30 bright stars, the brightest being 5th magnitude, spread over an area of 30′. M-46 covers about the same area of sky but is composed of over 100 faint stars.

Far left: "Two for the price of one" is what you get with the Double cluster in Perseus: two brilliant star clusters lying at different distances but along the same line of sight. Photo by Mace Hooley. Top left: NGC-457 is a bright star cluster surrounding the star Phi (ϕ) Cassiopeiae. Photo by Gary Bussman using an 11-inch f/10 SCT, 3M 1000 film, and a 10-minute exposure. Bottom left: M-11, the Wild Duck cluster in Scutum, is one of the richest groups of stars in the Milky Way. Photo by Jack Newton using a 16-inch f/5 Newtonian.



Open Clusters for Binoculars

Name	M#	R.A. (2000) Dec.	Con.	Diam.	d(pc)	N*	Mag.	Mag.*	Notes
Blanco 1	—	0h04.3m −29°56′	Scl	90′	250	30	4.5	5.02	Zeta Sculptoris Cluster
Collinder 463	—	1h48.4m +71°57′	Cas	36′	600	40	5.7	8.49	
NGC-752	—	1h57.8m +37°41′	And	50′	400	60	5.7	8.96	
Stock 2	—	2h15.0m +59°16′	Cas	60′	320	50	4.4	8.18	
NGC-869	—	2h19.0m +57°09′	Per	30′	2200	200	4.3p	6.55	Double Cluster
NGC-884	—	2h22.4m +57°07′	Per	30′	2300	150	4.4p	8.05	Double Cluster
IC 1805	—	2h32.7m +61°27′	Cas	22′	2100	40	6.5	7.87	
NGC-1039	M-34	2h42.0m +42°47′	Per	35′	440	60	5.2	7.33	
Collinder 33	—	2h59.3m +60°24′	Cas	40′	—	25	5.9p	—	
Melotte 20	—	3h22.0m +49°00′	Per	185′	170	50	1.2	2.88	Alpha Persei Moving Cluster
Pleiades	M-45	3h47.0m +24°07′	Tau	110′	125	100	1.2	2.87	
Hyades	—	4h27.0m +16°00′	Tau	330′	46	—	0.5	3.40	Taurus Moving Cluster
NGC-1647	—	4h46.0m +19°04′	Tau	45′	550	200	6.4	8.61	Near Hyades
NGC-1746	—	5h03.6m +23°49′	Tau	42′	420	20	6.1p	8p	
Collinder 62	—	5h22.5m +41°00′	Aur	28′	—	—	4.2p	—	
Collinder 464	—	5h22.0m +73°00′	Cam	120′	—	50	4.2p	—	
Collinder 65	—	5h26.0m +16°00′	Ori	220′	—	—	3.0p	—	
NGC-1912	M-38	5h28.7m +35°50′	Aur	21′	1320	100	6.4	9.53	
Collinder 69	—	5h35.1m +09°56′	Ori	65′	500	20	2.8p	—	Lambda Orionis Cluster
Trapezium	—	5h35.4m −05°23′	Ori	48′	450	—	3.7	—	In M-42, the Orion Nebula
NGC-1960	M-36	5h36.1m +34°08′	Aur	12′	1270	60	6.0	8.86	
Collinder 70	—	5h36.0m −01°00′	Ori	150′	430	100	0.4	1.69	Orion's Belt Stars
NGC-2099	M-37	5h52.4m +32°33′	Aur	24′	1350	150	5.6	9.21	
NGC-2168	M-35	6h08.9m +24°20′	Gem	28′	870	200	5.1	8.18	
Collinder 106	—	6h37.1m +05°57′	Mon	45′	—	20	4.6p	—	
NGC-2287	M-41	6h47.0m −20°44′	CMa	38′	700	80	4.5	6.91	
Collinder 121	—	6h54.2m −24°38′	CMa	50′	700	20	2.6	3.79	Omicron Canis Majoris Cluster
Collinder 132	—	7h14.4m −31°10′	CMa	95′	—	25	3.6	5.33	
Collinder 135	—	7h17.0m −36°50′	Pup	50′	—	—	2.1	2.71	
Collinder 140	—	7h23.9m −32°12′	CMa	42′	300	30	3.5	5.36	
NGC-2422	M-47	7h36.6m −14°30′	Pup	30′	480	30	4.4	5.68	
NGC-2437	M-46	7h41.8m −14°49′	Pup	27′	1660	100	6.1	8.68	Contains NGC-2438
NGC-2447	M-93	7h44.6m −23°52′	Pup	22′	1100	80	6.2:	8.20	
NGC-2451	—	7h45.4m −37°58′	Pup	45′	260	40	2.8	3.60	
NGC-2477	—	7h52.3m −38°33′	Pup	27′	1300	160	5.8	9.81	
NGC-2516	—	7h58.3m −60°52′	Car	30′	400	80	3.8	7p	
Collinder 173	—	8h04.0m −46°00′	Pup	370′	—	—	0.6p	—	
NGC-2546	—	8h12.4m −37°38′	Pup	41′	1000	40	6.3	8.22	
NGC-2548	M-48	8h13.8m −05°48′	Hya	54′	610	80	5.8	8.23	
Ruprecht 64	—	8h37.4m −40°06′	Vel	67′	—	80	—	9p	
NGC-2632	M-44	8h40.1m +19°59′	Cnc	95′	160	50	3.1	6.30	The Beehive
IC 2391	—	8h40.2m −53°04′	Vel	50′	180	30	2.5	3.63	
NGC-2682	M-67	8h50.4m +11°49′	Cnc	30′	800	200	6.9	9.69	
NGC-3114	—	10h02.7m −60°07′	Car	35′	900	—	4.2	7.31	
Ruprecht 161	—	10h08.8m −61°12′	Car	33′	—	—	—	11p	
IC 2602	—	10h43.2m −64°24′	Car	50′	150	60	1.9	2.77	Theta Carinae Cluster
NGC-3532	—	11h06.4m −58°40′	Car	55′	410	150	3.0	7.08	
Collinder 285	—	12h03.0m +58°00′	UMa	1400′	23	—	0.4	2p	Ursa Major Moving Cluster
Melotte 111	—	12h25.0m +26°00′	Com	275′	80	80	1.8	4.35	Coma Berenices Cluster

Column 1: name of cluster. **Column 2:** Messier number. **Column 3:** coordinates for epoch 2000.0. **Column 4:** constellation in which cluster lies. **Column 5:** diameter in arc-minutes. **Column 6:** distance in parsecs. **Column 7:** number of stars. **Column 8:** integrated V magnitude; "p" denotes photographic magnitude. **Column 9:** V magnitude of brightest cluster member; "p" denotes photographic magnitude. **Column 10:** Notes.

A perfect target for binoculars, M-35 in Gemini is composed of some 200 stars in an area the size of the Full Moon. Nearby is the cluster NGC-2158, equal in size to M-35 but nearly six times more distant. Photo by Bill Iburg using an 8-inch f/1.5 Schmidt camera, Ektachrome 400 film, and an 8-minute exposure.

Curiously, a faint planetary nebula, NGC-2438, lies in front of M-46 and so appears to float inside the group of faint stars. This little planetary looks like a fainter rendition of the famed Ring nebula in Lyra but is more difficult to spot not only because it's dim, but also because it is surrounded by so many field stars. If you own large binoculars, try to spot this tiny oval smudge of light within the boundaries of M-46.

Canis Major: M-41 and More

Strikingly bright and easy to find, Canis Major the Large Dog also has its share of bright star clusters. Find Sirius in this constellation and sweep your binoculars 4° due south. You'll come upon a patch of misty light slightly larger than the Moon. With close inspection, you'll note that this large patch is composed of dozens of stars. This is M-41, another of the bright Messier clusters large enough for easy binocular observing. It contains 80 stars of 7th magnitude and fainter, giving it a total magnitude of 4.5.

There's also Collinder 121, otherwise known as the Omicron Canis Majoris cluster because it's centered on the bright star Omicron (*o*) CMa. Collinder 121 holds only 20 stars in an area spanning nearly a degree, but its stars are bright making the field worthwhile for binocular observers. Larger and brighter yet is Collinder 132, a sprinkling of stars just a few degrees south of Canis Major's hind legs.

Having surveyed a good many of the winter sky's best binocular star clusters, you should have a good feel for the different brightnesses, sizes, and concentrations of these relatively young objects in our galaxy's disk. If you're hungry for more examples, the table on this page lists a total of 49 clusters in the winter and early spring skies that you can observe with binoculars. Armed with this list, a star atlas, and your binoc's, you'll be all set for scanning the winter skies.

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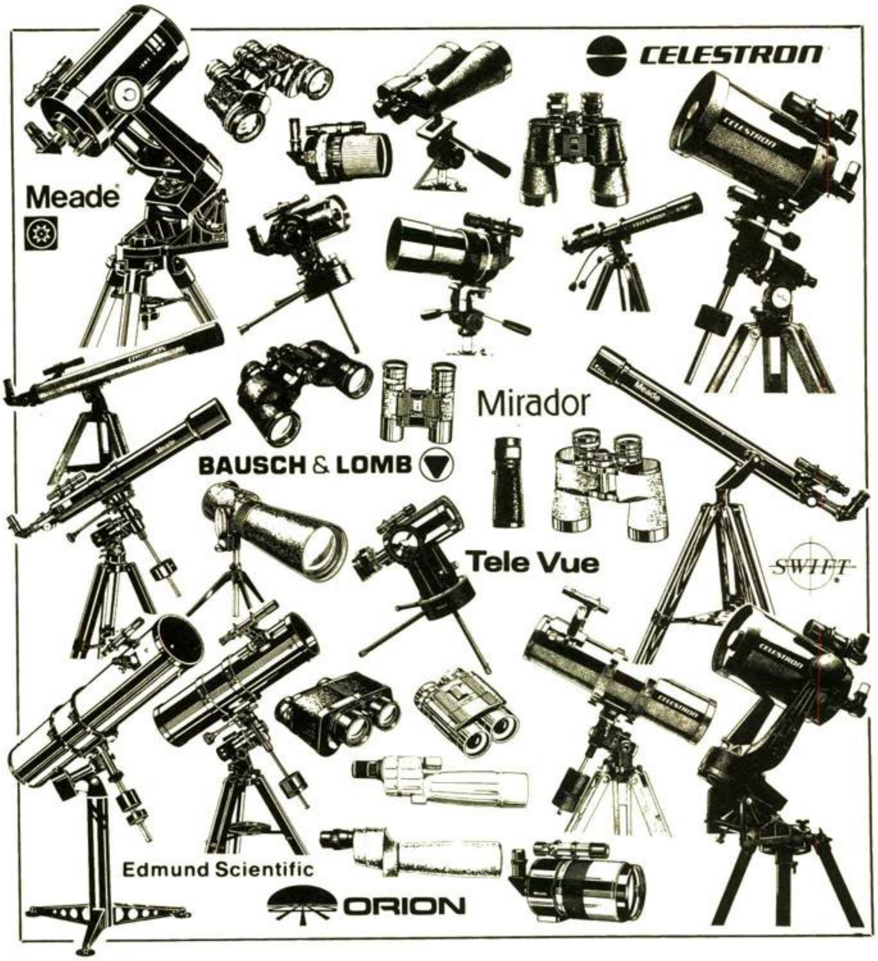

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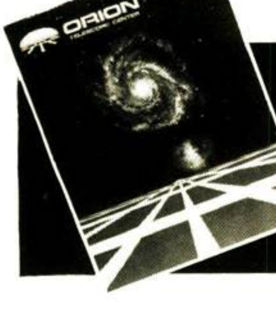

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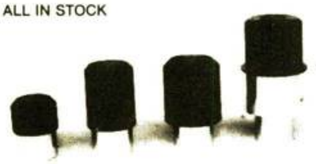

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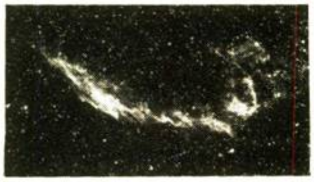

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Zepernick, Cresskill, NJ

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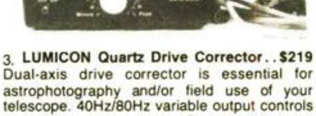

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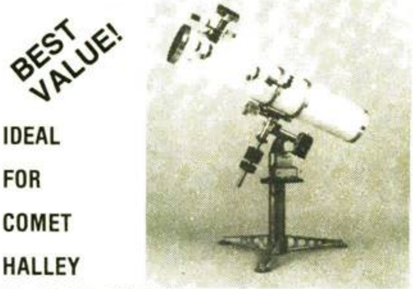

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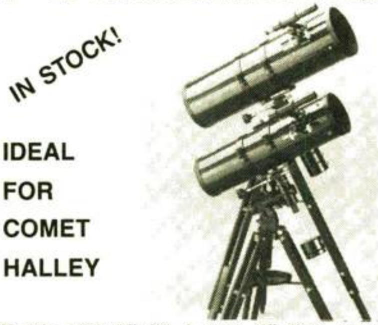

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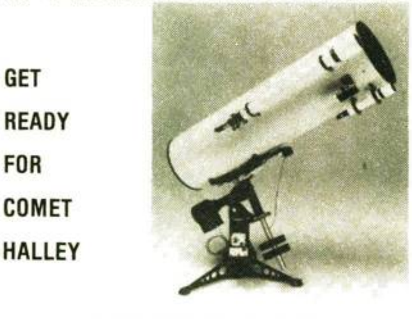

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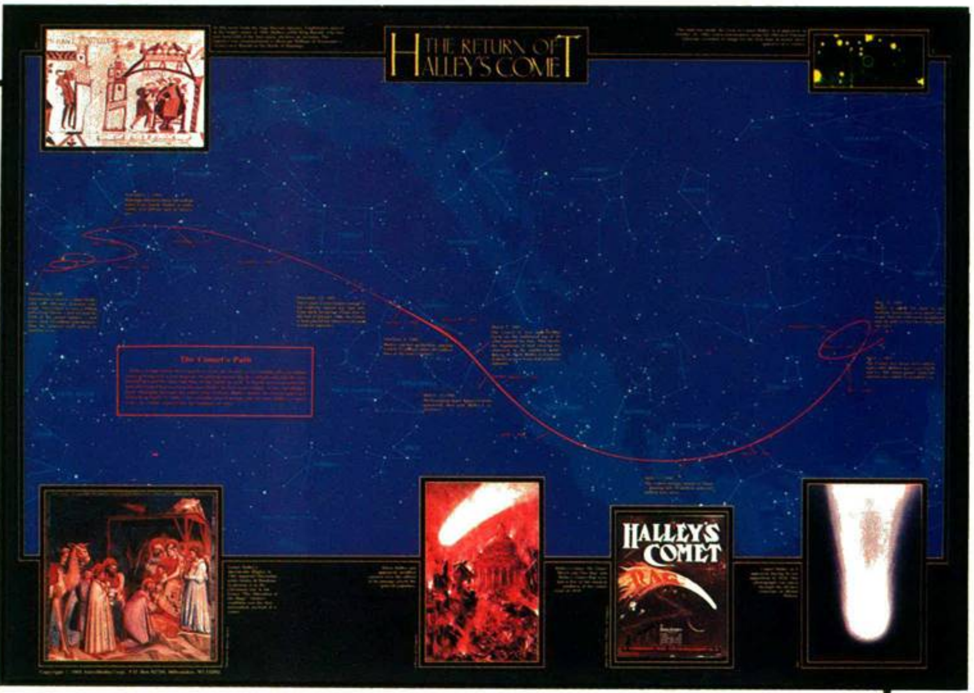
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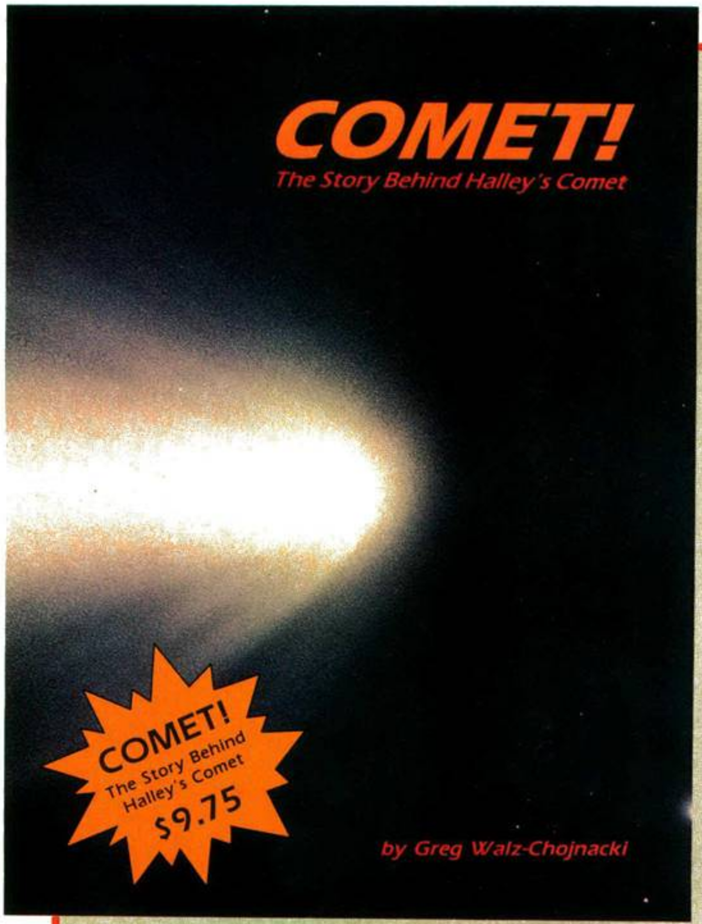
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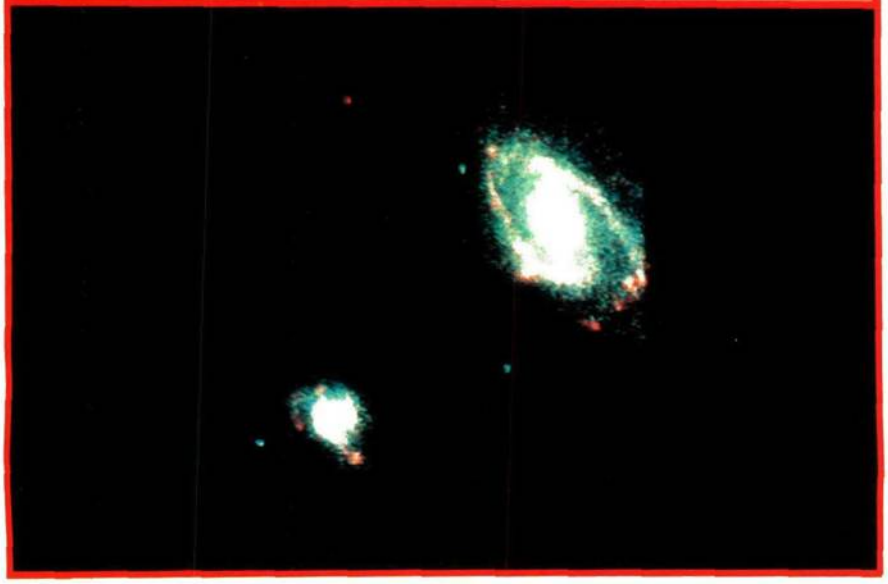
ASTRONOMY
AstroNews

A new study of interacting galaxies seems to show that as two galaxies pass each other, tidal effects distort the material in each galaxy, but — contradicting earlier notions — the galaxies do not exchange material. The study was done by William Keel of Kitt Peak National Observatory, Robert Kennicutt, Jr. of the University of Minnesota, E. Hummel of the Max Planck Institute, and J.M. van der Hulst of the Westerbork Radio Observatory. Among the galaxies studied were NGC-274/NGC-275 in Cetus (above) and NGC-1241/NGC-1242 in Eridanus (below). National Optical Astronomy Observatories photo.



Cool Stars in Santa Fe

The Fourth Annual Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun was held in October 1985 in Santa Fe, New Mexico. The workshop, hosted by the Astrophysics Research Center of New Mexico Tech, attracted researchers from all over the world to discuss current frontiers in stellar and solar astronomy. The main focus this year was on activities by small and large atmospheric structures on stellar surfaces.

The nearest star whose surface we can study is, of course, the Sun. Its proximity allows us to resolve features several hundred kilometers long and velocities of a few kilometers per second. But, according to Eugene Parker, a highly-reputed theorist at the University of Chicago, these measurements are just not accurate enough to understand what is really happening there.

Observations show that magnetic flux boils out of the solar surface, then reverses direction and sinks back beneath it. The end points of fibrils — tubes of magnetic flux — entrap high-temperature plasma in the solar corona and wander around the Sun's surface at approximately half a kilometer per second. The crucial details of these fascinating phenomena lie beyond our current instrumental resolution.

According to Parker, studying the fine structure of the Sun's surface magnetic field should tell us something about how the Sun transports and deposits energy in its upper atmosphere. Parker described extremely thin sheets of electric current that loop from the Sun's photosphere up into the corona and back; these cover hundreds of thousands of kilometers and deposit particles and heat along the way. This model, expounded by Parker and other theorists, solves the long-standing problem of how energy heats the solar corona by using topological changes in sheets of electric current at scales of a few dozen meters or so.

Jan Christiansen-Dalsgaard of the Institute for Astronomy, University of Aarhus, Denmark, discussed observations of sound waves in the Sun. This new branch of astronomy, termed helioseismology, lets astronomers "see" inside the Sun. Christiansen-Dalsgaard said the new observations imply, unexpectedly, that some internal zones may be rotating slower than the Sun's surface. Present models of how magnetic fields are generated rely on rapid motions in the convection zone deep within the Sun. These models have successfully predicted the 22-year magnetic cycle and the differential rotation that causes sunspots to migrate toward the solar equator, but they require that layers inside the Sun rotate faster than its surface.

Peter Gilman and Edward Deluca of the High Altitude Observatory in Boulder, Colorado, think they have a solution to this paradox in a new scenario for magnetic flux production. In their model, instead of the whole convective zone being the dynamo, the magnetic fields originate from a thin layer between the convection zone and the radiative core of the star. Fred Walter of the University of Colorado indicated a way to check out the Gilman and Deluca model. His observations of magnetic activity in late type-A and early type-F main sequence stars show that these stars have very shallow convection zones, therefore the turnover time (the time it takes a convection cell to traverse the entire convection zone) is very small. As a result, we should be able to see the effects of the field-generating mechanism on the surface of these stars.

Although we cannot directly observe the surface structure of stars other than the Sun, astronomers can measure the first few sound-wave modes of vibration for some nearby stars. Robert Noyes of the Harvard-Smithsonian Center for Astrophysics presented the first detection of acoustic waves on Procyon, ε Eridani, and α Centauri. Though only limited information can be derived from the data, the observations show that stellar seismology works and promises to be a useful technique for investigating the interiors of stars.

The Sun, as a very typical cool dwarf star, displays variable solar magnetic phenomena that should exist on other similar stars as well. Surveys of long-term stellar variations provide unique opportunities to test theories about the dynamo that drives the 22-year magnetic cycle of the Sun. Sallie Baliunas of the Harvard-Smithsonian Center for Astrophysics discussed the current evidence for long-term stellar activity cycles. She indicated that as many as 85% of all the late-type stars have periodic cycles or sporadic fluctuations in their chromospheric activity. She finds evidence for cycle periods ranging from 2 years to as long as 60 years.

The long-standing problem of measuring stellar mass loss was reviewed, rather skeptically, by Stephen Drake of SASC Technologies. Typically, the estimates of different researchers for the loss

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rate of a given star will differ by factors of 10 to 100. Drake explained that part of these differences arise from inaccurate distances and intrinsic variations of the mass loss rates of various stars. Some, however, arise from different values of "constants" in the mass loss equation chosen by the various researchers. He questioned whether astronomers should use these factors at all, since they apparently aren't yielding physical insight into the mass loss mechanism.

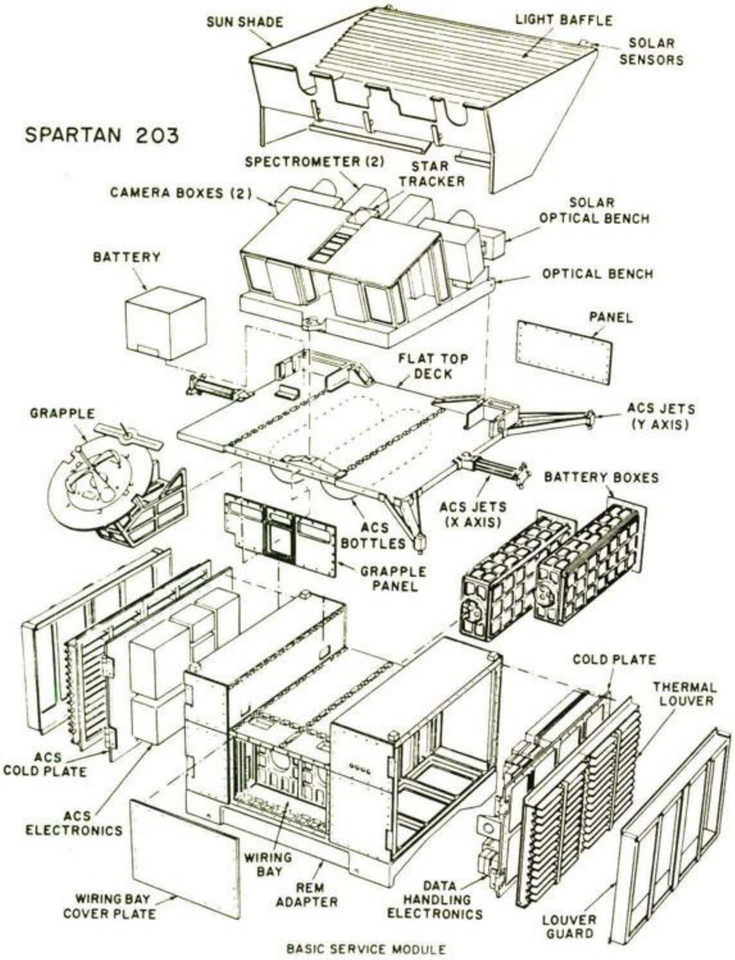
Workshops and conferences aren't all data, theories, and models. Although it is absent from the official record, gossip is plentiful at such events, as it is in the astronomical community as a whole. To a degree that few laypeople are aware of, gossip and intrigue are strong internal forces that help determine future scientific trends. At the workshop, gossip revealed a very controversial debate over the value of large, unique, highly-expensive projects (such as the Hubble Space Telescope) as compared to multitudes of small, cheap, dedicated ones. Though no resolution was in sight at the workshop, the feeling was that single large projects are ultimately harmful since they consume funds better spent on a greater number of small research programs, which in the end may produce more astronomy. It will be interesting to see how this debate works itself out in the years to come! *Israel Oznovich.*

A Spartan Looks at Halley

As Comet Halley swings toward the Sun, the Shuttle *Challenger*, which lifts off on January 22, will carry a comet observatory into orbit to take pictures and record comet spectra. Known as Spartan Halley, the tiny spacecraft will spend nearly two days observing the comet as it approaches perihelion, the time of its closest approach to the Sun and also its peak activity.

Two cameras aboard Spartan Halley will record outbursts, or jets, of material from the coma and the shape and development of the tail. The cameras are flight-qualified Nikon F3 35mm cameras with telephoto lenses, one equipped with a 105mm f/2 lens and the other with a 135mm f/1.8 lens. They will take a total of 130 photographs. The cameras are loaded with QX-851 thin-base color film (ASA 800/1600).

Also aboard Spartan Halley are ultraviolet spectrometers that will measure elements and compounds making up the gases in the comet's tail and head. The spectrometers will observe wavelengths in the ultraviolet between 128 and 340 nanometers. Charles Barth, head of the scientific team from the University of Colorado, expects the instruments to measure oxygen atoms and hydroxyl radicals; this will reveal how much and how rapidly water escapes from the icy



nucleus as well as how it breaks down in the bright sunlight. Spartan Halley's instruments will also be able to detect carbon, nitrogen, and sulfur atoms and molecules. If those elements are in the gaseous coma, more complex molecules like ammonia, methane, and carbon sulfide may be present in the icy nucleus.

Spartan Halley will observe the comet when it is about 88.5 million kilometers from the Sun and about 231 million kilometers from Earth. When Comet Halley reaches perihelion, it will appear within 7° of the Sun as seen from Earth. To be able to view the comet so near the brilliant disk of the Sun, a double set of light traps have been incorporated into the experiment. Internal baffles protect the spectrometer's entrance apertures and a large, black shade mounted on the spacecraft reduces the possibility of stray earthlight entering the instruments.

Astronauts aboard the Shuttle will use the remote manipulator arm to deploy and retrieve the Spartan Halley spacecraft. After deployment, Challenger will move eight kilometers away, leaving Spartan Halley alone for its 45-hour mission. An onboard microprocessor will conduct the mission: pointing the sensors to locate the Sun and a target star (Canopus), finding Comet Halley's position according to an ephemeris stored in the memory, sequencing the cameras, making scans across the coma and tail, recording the data, and finally shutting down the experiment to wait for the Shuttle's return. *Rionda Osmon-Jouchoux and John Glaab.*

Spartan Halley uses a Spartan spacecraft to carry experiments and to supply battery power, pointing mechanisms, a tape recorder, electronics, and thermal controls for those experiments.

Radar Probes Asteroids

Radar astronomy has made great strides since the first echoes were bounced off the Moon four decades ago. In the 1960s, measurements of the time it took a radar echo to return from Venus tied down the length of an astronomical unit to within a kilometer, while other studies determined the rotation rates of both Venus and Mercury. Radar penetrated the clouds of Venus to make the first maps of the planet's hidden surface. Radar observations have also been made of Mars and members of the Earth-approaching, or Apollo, asteroids.

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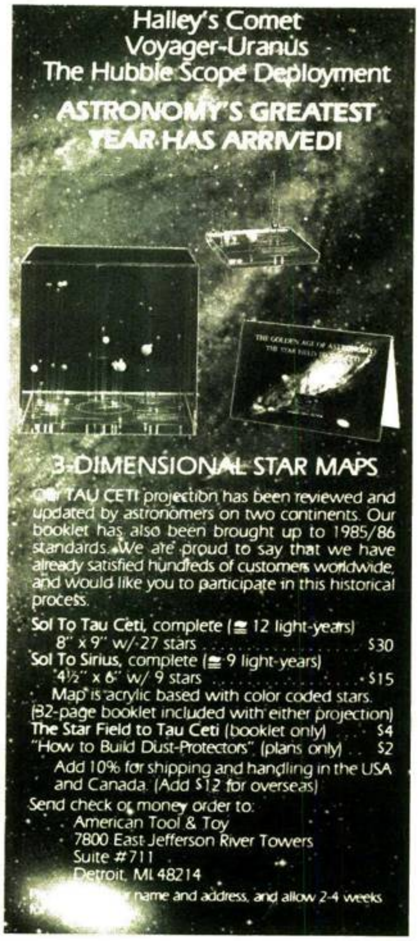
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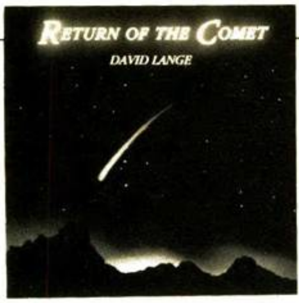

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Now Stephen Ostro, Donald Campbell, and Irwin Shapiro, writing in the August 2, 1985 issue of *Science*, have reported the results of a series of radar observations of asteroids in the main belt between Mars and Jupiter.

Radar observations provide information on the surface characteristics of asteroids at scales between a few centimeters and a few kilometers; moreover, they can set limits on the bulk density and metallic concentration of the surface layers. Radar studies complement optical measurements because radar waves penetrate somewhat below the surface before bouncing back to Earth, unlike visible light which reflects off the topmost layer.

Ostro and his colleagues used the 1000-foot Arecibo telescope in Puerto Rico to study 20 main-belt asteroids. These ranged in size from 1 Ceres, which has a diameter of about 1000 kilometers, to 80 Sappho, which is just over 80 kilometers across.

The astronomers estimated the asteroids' surface roughness by broadcasting circularly polarized 2,380 MHz radiation toward the target asteroid. Surfaces that appear smooth at the observing wavelength normally return signals with a reversed sense of polarization, and rough surfaces return echoes with the same polarization as the transmitted signal. The ratio of signals with reversed polarization to those with unchanged polarization gave Ostro and his co-workers a good idea how rough the asteroid surfaces were.

The results surprised them. It appears that 2 Pallas, one of the largest asteroids, is extremely smooth. Planetary scientists believe large asteroids are covered by a loosely-compacted layer (or regolith) composed of large and small rocks shattered by meteorite collisions. Since Pallas has sufficient gravitational attraction to retain most of this debris, it should have a substantial regolith and appear quite rough, which it doesn't.

A possible explanation for the discrepancy is that C-type (carbonaceous) asteroids, such as Pallas, are made up of more friable materials than the stony or metal-rich asteroids; therefore, their surfaces can be ground down more finely than other asteroid types.

The radar measurements also provide information on the structure of asteroid surfaces at much larger scales. These results are more difficult to interpret since they require a knowledge of the asteroid's shape and rotation characteristics. Ostro and his colleagues suggest that at scales larger than a few meters, the asteroids are substantially rougher than the Moon. This means that asteroids are fairly smooth on a small scale but display major topographic irregularities.

These larger features could result from the way an asteroid responds to a big impact. Observations of the martian moons have shown that shock waves from large impacts appear to travel through the object, producing severe disruptions on the side opposite the impact point. It's probable that similar processes operate on the larger asteroids, which are bigger than the martian satellites but smaller than the terrestrial planets.

From asteroid radar reflectivities, Ostro and his co-workers estimated the amount of metal in the surface material. While pointing out that such estimates have large uncertainties, they report that asteroid 16 Psyche appears to be very metal-rich. It may, in fact, be the metallic core of a once larger asteroid that differentiated chemically before breaking up in a collision. If true, this would make Psyche the largest piece of semi-refined metal in the solar system! Paradoxically, 97 Klotho, a metal-rich M-type asteroid like Psyche, appears *not* to have a particularly metallic surface.

These observations re-emphasize how diverse asteroids are — a fact already evidenced by studies at visible and infrared wavelengths — and confirm the value of studying asteroid populations further. Asteroid astronomers hope to learn more from the much-awaited flyby of asteroid 29 Amphitrite by the Galileo spacecraft on its outbound path to Jupiter. *John K. Davies.*

Hipparcos Satellite to Re-Catalog the Stars

After observing a "new star" in 134 B.C., the Greek astrologer, astronomer, and mathematician Hipparchus felt compelled to investigate the habits of stars further. By 129 B.C., he had completed a monumental stellar catalog, listing 850 stars complete with their brightnesses (rated on the now-familiar magnitude scale) and their zodiacal longitudes and latitudes. His measurements were accurate enough that Ptolemy was able to use them centuries later, as did Edmond Halley much later still.

Today, star catalogs list as many as 250,000 stars. These catalogs have evolved, however, about as far as they can, since observations from the Earth's surface face ultimately insurmountable obstacles to accuracy from the vagaries of atmospheric refraction, the limitations of photographic materials, and the gravitational deformations of astrometric equipment.

To surmount these, the Hipparcos satellite (High-Precision Parallax Collector) will be launched in 1988 to carry out a complete stellar survey. For about 30 months, this satellite will gather positional data on 100,000 stars brighter than magnitude 12. In so doing, it will scan the entire celestial sphere at least five times.

A "ride-along" package, called the Tycho experiment, will use one of the spacecraft's auxiliary sensors to perform

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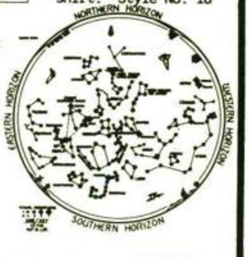

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a more general astrometric and photometric survey of about 400,000 stars whose measurements will be about 10 times coarser than the primary data. By 1994, the project scientists hope to combine the results from Hipparcos with those from the Hubble Space Telescope to produce two extremely precise catalogs.

Both the Hipparcos astrometric and the Tycho astrometric and photometric catalogs will boost stellar positional accuracy to approximately 2.5 milli-arc-seconds for about 95,000 stars. Still higher accuracies will be obtained for stars brighter than magnitude 9. Even stars as faint as magnitude 12 will have 4 to 4.5 milli-arc-second errors. To put this into perspective, the new catalog's *worst* measurements will still be about 5 to 10 times better than the best ground-based work can provide.

Hipparcos' exceptional level of accuracy will allow precise absolute stellar parallaxes to be calculated. This will become especially valuable in calculating true distances to stars and, therefore, in determining their intrinsic brightnesses, a key data point for astrophysicists seeking to understand how stars work. Data from Hipparcos will also be used to evaluate the stellar content of nearby galaxies and clusters of galaxies. Using photometry and spectroscopy to study the chemical evolution of selected galaxies, astronomers working from Hipparcos data hope to establish a more exact cosmic distance scale.

The satellite will have a diffraction-limited reflecting telescope with a 290mm aperture and a 37 arc-second field of view. Hipparcos will be placed into a near-geosynchronous orbit inclined 1° to the equator. The satellite will carry out uninterrupted observations (except for four daily Earth-occultations and the occasional lunar occultation) of stars passing across the telescope's field of view while other instruments scan the celestial sphere.

What would astronomer Hipparchus have made of it all? No doubt he'd be delighted — both by the precision now achievable and by a universe filled with more stellar wonders than he could ever have imagined! *Aldo G. Rabaiotti.*

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February 15
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February 15-16
IAPPP Symposium on Automatic Photoelectric Telescopes, Phoenix, Arizona. Contact: Russell M. Genet, Fairborne Observatory, 1357 N. 91st Pl., Mesa, AZ 85207. Phone (602) 986-2828.

March 26-29
National Convention of the National Science Teachers Association, San Francisco, California. Contact: Matthew R. Murphy, NSTA, 1742 Connecticut Ave., N.W., Washington, DC 20009.

April 11
International Halley Day of Harmony. For more information, contact: James B. Harris, Jr., Florida Space Week Committee, P.O. Box #291, Sharpes, FL 32959. Phone: (305) 632-9139.

April 18-19
Wisconsin Society of Science Teachers Annual Spring Convention, Appleton, Wisconsin. Contact: Floyd R. Henschel, 504 W. Maple Ave., Beaver Dam, WI 53916. Phone (414) 885-4415.

April 19
Astronomy Day. For more information, contact: Gary Tomlinson, Astronomy Day Coordinator, Astronomy League, Chaffee Planetarium, 54 Jefferson S.E., Grand Rapids, MI 49503. Phone (616) 456-3985.

April 19
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April 23-26
MAPS (Middle Atlantic Planetarium Society) Annual Spring Meeting, Wheeling, West Virginia. Contact: Steve Mitch, Oglebay, Wheeling, WV 26003.

May 5-10
Texas Star Party, Prude Ranch, Fort Davis, Texas. Contact: Carol Rodgers, 128 N. Commerce, Burleson, TX 76028.

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Fifth Annual Space Development Conference, Seattle, Washington. Contact: 1986 Space Development Conference, Dept. C3, P.O. Box 30869, Greenwood Post Office, Seattle, WA 98103-0869.

June 19-21
IAPPP Symposium on Photoelectric Photometry, Mercyhurst College, Erie, Pennsylvania. Contact: Robert C. Reisenweber, Rolling Ridge Observatory, 3621 Ridge Parkway, Erie, PA 16510. Phone (814) 899-2560.

June 22-26
168th Meeting of the American Astronomical Society (professional meeting), sponsored by Iowa State University, Ames, Iowa. Contact: AAS, 1816 Jefferson Pl., N.W., Washington, DC 20036.

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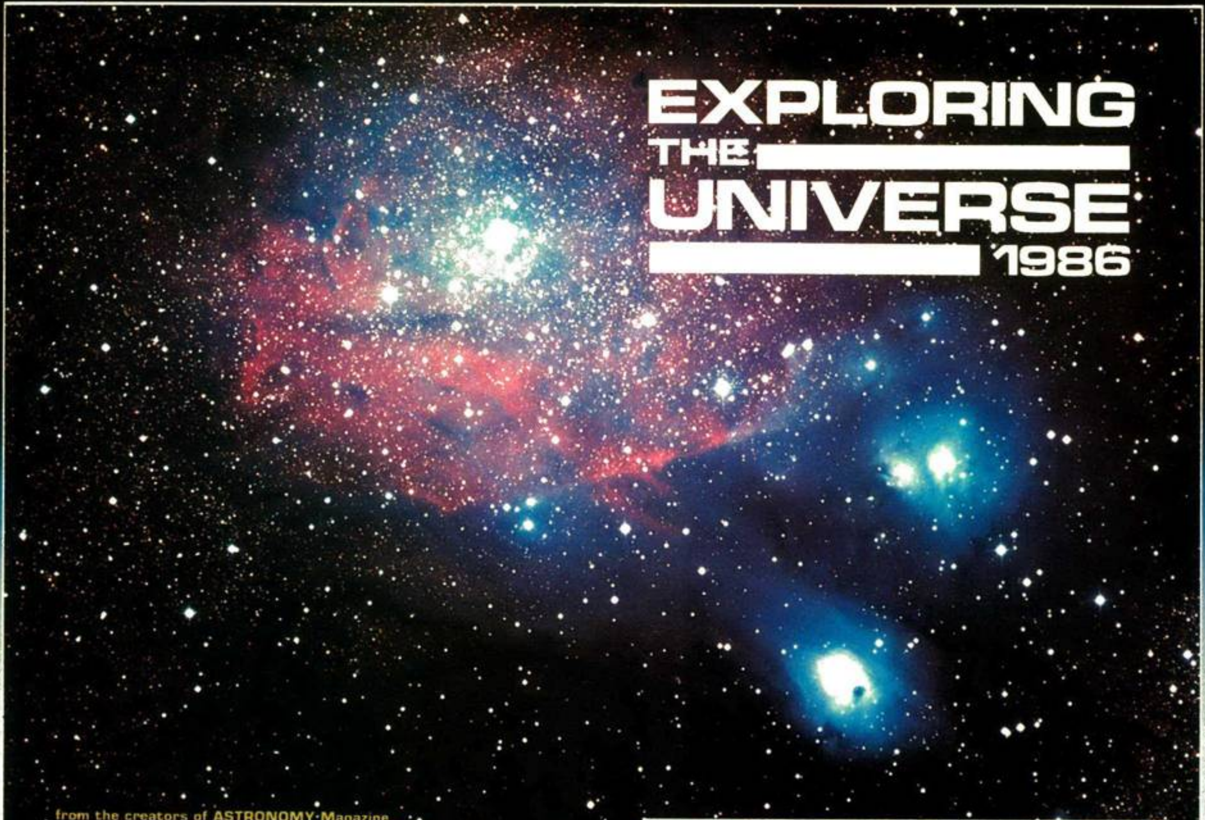
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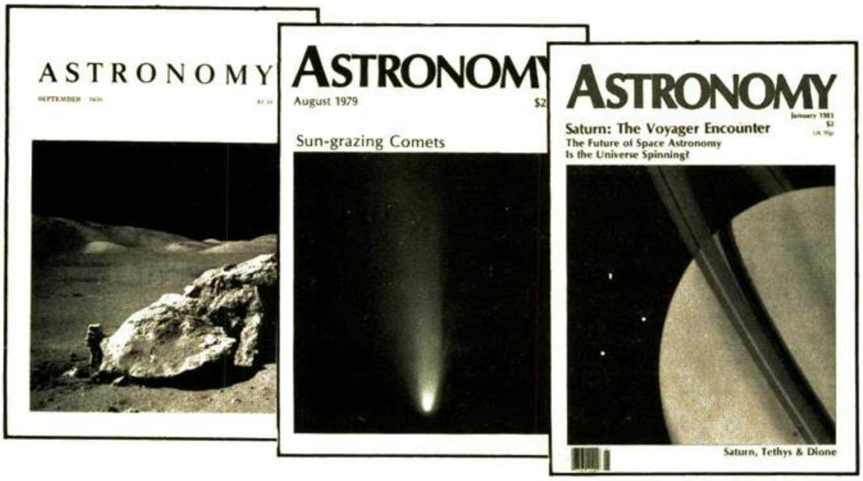
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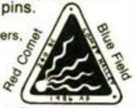

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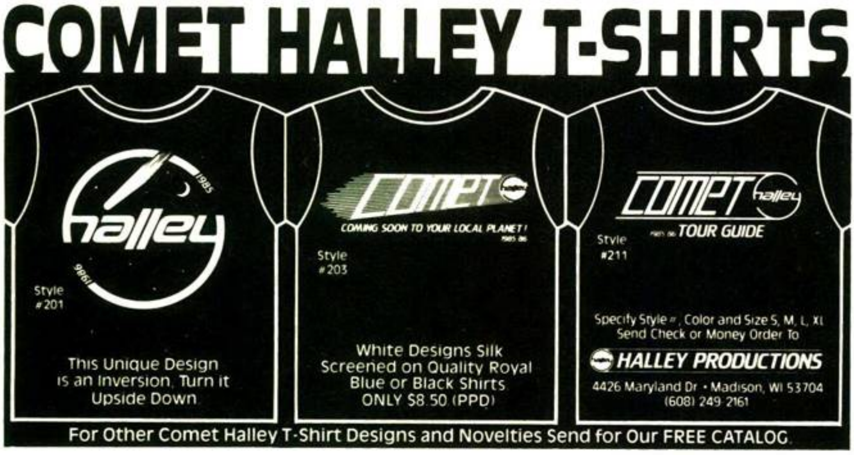

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Ad-Libs Astronomics...............60-61
Adorama Camera Inc.................87
American Tool & Toy................77
ARCsoft Publishers.................76
Astro-Alaska.......................52
Astro Cards........................79
Astroline Products.................87
Astronomy Place, Inc...............53
Astronomy Tours International......77
Bennett-Sipes Company..............27
Bergen County Camera...............87
Berger Bros. Camera Exchange.......78
Blankenship Enterprises............87
Bushnell Optical Company..........110
California Adventure Travel........75
California Natural History Tours...87
California Telescope Company....29,51
Celestial Systems..................86
Celestron International...........112
Celmark............................27
Conference Travel of Canada........87
Cosmic Connections, Inc............86
Cosmic Creations...................86
Cotton Expressions..............79,88
Coulter Optical Co.................84
Countdown..........................89
Davionx............................86
Edelman's.......................36-37
Efstonscience Inc..................75
Focus Camera, Inc..................72
Fotoflytes.........................76
Fujinon............................76
Galaxy Medals......................88
Halley Productions.................85
Halley's World.....................87
Hamilton Collection................31
Hayes & Nolly Productions..........78
HC Design..........................86
Hearts of Space....................78
Horizon Productions................76
Impact Merchandising Corp..........27
IPMC...............................88
Jim's Mobile Industries............85
Kowaliski Diversified..............79
Lumicon.........................70-71
Mack Optical.......................78
Meade Instruments.................2-3
Meteorites.........................85
New England Astro-Optics...........86
New York Camera....................84
NW Telescopes Inc..................86
Oasis Art..........................86
Optica b/c.........................88
Optics Ohio........................86
Orion Telescope Center..........68-69
Parks Optical...................96-97
Pauli's Discount Optics............85
Pich of the Litter.................88
Pinboys............................85
Quasar Optics......................88
RCK Scientific.....................85
Ritchey-Prints.....................85
Scope City.........................23
Solar Productions..................88
Spectrum...........................85
Starfinders Company................88
Star Tracker.......................86
Stellar Vision, Inc................75
TeleVue............................33
Texas Nautical Repair Co...........76
Time-Life Books....................25
Towson Photo Supply................87
Tuthill, Roger W., Inc.............53
Willmann-Bell, Inc.................88
Zephyr Services....................75

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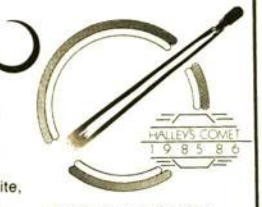

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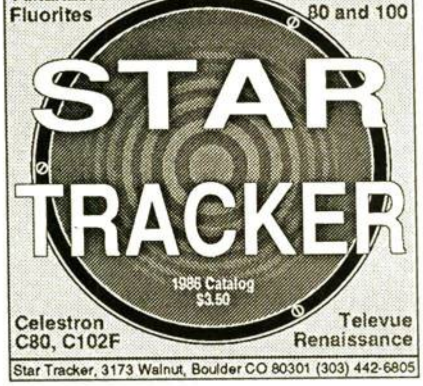

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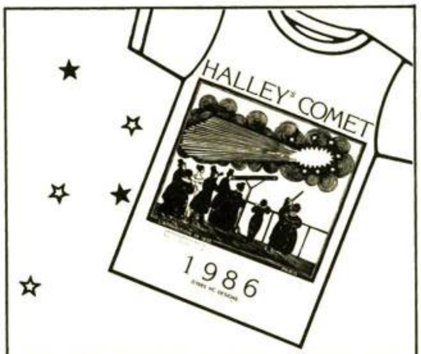

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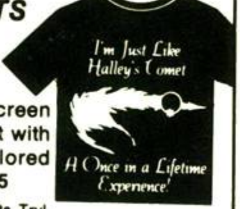

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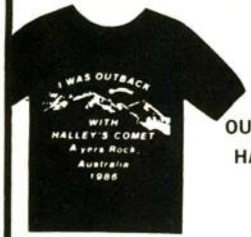

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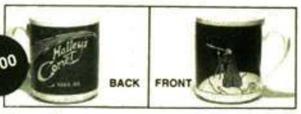

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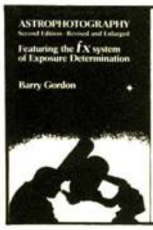
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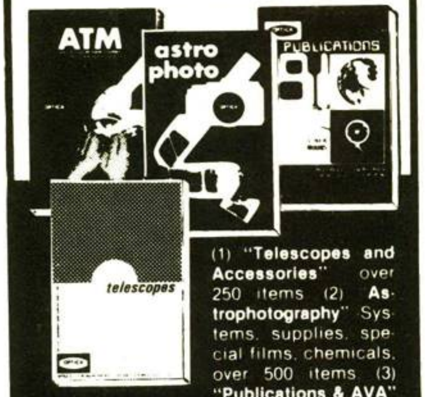
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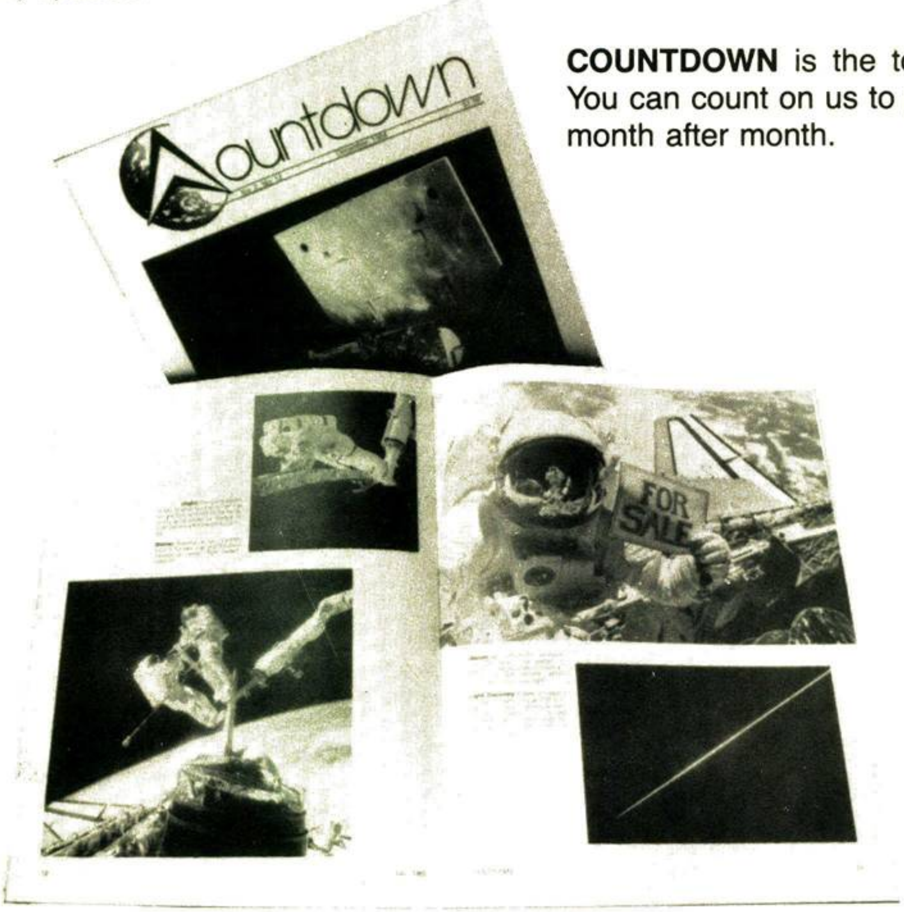

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The Mysterious Cosmic X-Ray Background

by Barry Parker

When you hear the word x-ray you probably think of your last trip to the dentist. But have you ever really considered what an x-ray is? An x-ray is a particle of energy, or photon, about a thousand times more energetic than a particle of visible light. Because an x-ray's wavelength is much shorter and its frequency is much higher than that of a light photon, it has the energy to easily pass through your tooth.

X-rays are important to astronomers because they signal areas of high-energy emission. In other words, objects that send off large amounts of x-rays are releasing huge amounts of energy. This can occur for various reasons, such as material spiraling onto a black hole, a neutron star, or a white dwarf. These single, identifiable objects are useful for studying the distribution of matter in space. The higher the x-ray emission from an object like a neutron star, the greater the amount of material that is falling onto it.

Not all x-rays can be attributed to discrete sources, however: The entire sky is filled with a weak background glow of x-rays. What is the mysterious source of this overall low-level radiation?

This is a relatively new question for astronomers since, as far as anyone knew, the x-ray universe didn't exist before 1947. Unlike the visible and radio parts of the electromagnetic spectrum, x-rays are blocked by our atmosphere; we must rise above it to detect them. Until the development of space technology after World War II, astronomers had no way to do this. By the early 1960s, rockets and satellites had become common enough to use for astronomical research, and x-ray astronomy — a field critical to the understanding of the universe — began in earnest.

The beginnings of x-ray astronomy date back to the 1940s when a number of scientists became interested in the Sun as a possible source of x-rays. If the Sun was a source, other stars might be also, and they could tell us a great deal about conditions elsewhere in the universe by their x-ray emission.

After the war the United States, using captured German V-2 rockets, launched a flight to detect x-rays from the Sun. The V-2 experiment showed that the Sun was indeed an x-ray source. It was, however, such a weak source that few scientists had any further interest in cosmic x-rays for many years to come. At the time it was believed that x-rays were detected from the Sun only because it was a mere 93 million miles away. No one thought that x-rays from other stars many light-years distant could be detected.

The Italian physicist Riccardo Giacconi was well aware of this fact when he joined American Science and Engineering, a research firm, in the early 1960s. The company, based in Cambridge, Massachusetts, had been established to study the effects of nuclear fallout on the atmosphere. But by the time Giacconi arrived, the company's directors had become interested in new areas of research. Giacconi had been working on cosmic rays at Princeton University where he developed an interest in the possibility of detecting x-rays from space. He realized that x-rays could penetrate the interstellar medium that permeates the Galaxy; if we could detect them, we would have a new window to the universe. We would see space as it had never been seen before.

Upon joining the company, Giacconi established an x-ray program. His first task was to design an instrument capable of detecting weak celestial x-rays. Giaconni and his colleagues created a detector that reflected x-rays from a large surface onto a small collector about the size of a silver dollar. An electrical signal was generated each time an x-ray struck the collector, permitting a measurement of the radiation's intensity.

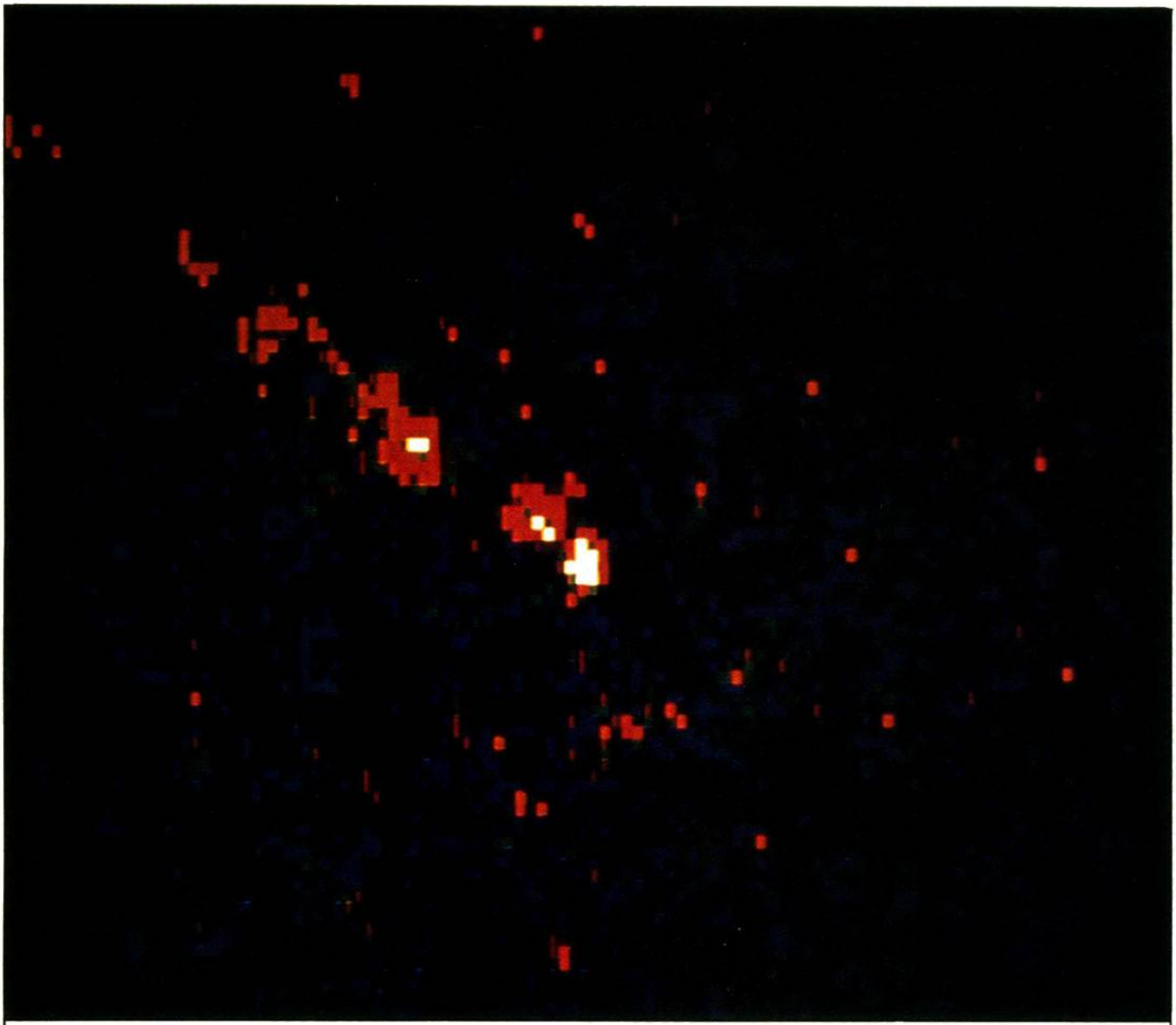
The detector was placed aboard an Aerobee rocket and at midnight on June 12, 1962, it lifted off. Giacconi and his colleagues had only a faint idea of what they would detect, and there were indications that they might not see anything at all. But to their delight they found a powerful x-ray source in the constellation Scorpius — a source now called Scorpius X-1. Furthermore, as the detector moved across the sky searching for other sources, it inadvertently made an important discovery: There were x-rays coming from *everywhere*. They were faint and diffuse, but they were everywhere. The Aerobee probe had discovered that the universe seemed to be seething in a low-level, unidentifiable "glow" of uniform x-ray radiation, which was present everywhere the detector pointed.

What was causing this diffuse x-ray radiation? Where was it coming from? The serendipitous discovery brought about more missions, more data, and more research. Astronomers have since learned a great deal about the x-ray sky, but even today we're still not sure what causes the diffuse background glow that is seemingly present throughout the universe.

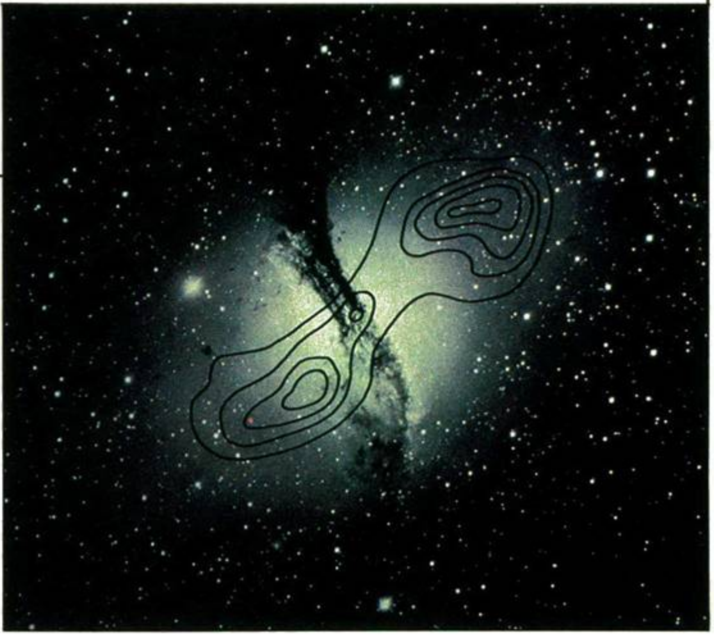
We know there is no such background glow in the visible part of the spectrum. If we look at the night sky, we see stars and other bright objects set against a dark background. The x-ray sky, however, consists of "bright" x-ray sources against a diffuse glow of x-rays.

Scientists know of two ways to generate x-rays. The first method starts with a heavy atom containing an electron in a low energy level. If the electron makes a jump to an even lower energy state, it will emit a photon at an x-ray wavelength. Since heavy atoms are rare in space, this seems an unlikely cause of the background x-rays.

The second method of creating x-rays is called



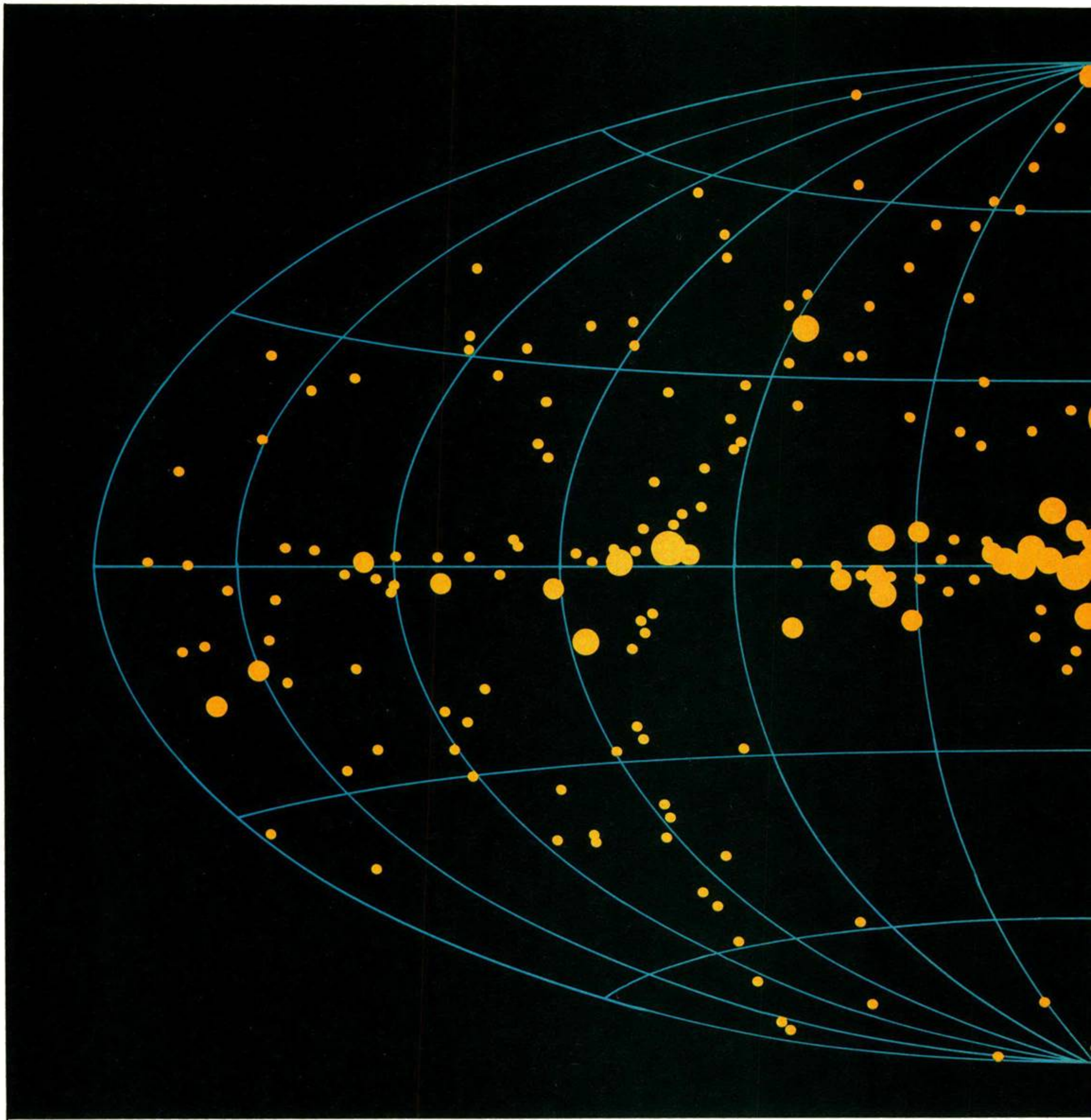
The nearby active galaxy NGC-5128 in Centaurus is one of the sky's strongest sources of high-energy radiation. The image of NGC-5128 below shows overlaid contours of radio emission that reveal a jet of material flowing out from the nucleus. The Einstein x-ray image of this galaxy (above) shows that this jet (extending from center to upper left) is emitting x-rays. NASA photos.



bremsstrahlung (German for "braking radiation"). Let's assume we have a positively charged particle, such as a proton, and a high speed electron. The proton will deflect the electron if it passes nearby. Whenever a charged particle is accelerated (deflection is a form of acceleration), it gives off radiation. If the acceleration is great enough the radiation will be in the form of x-rays.

Is this the process giving rise to the background x-rays? There's one clue that would confirm this hypothesis: the presence of a gas composed of both positive and negative particles, or in other words, a plasma. Since the electrons must also be moving fast, the plasma would have to be hot. The solar corona is such a plasma and it emits x-rays.

Is there a hot plasma spread throughout the universe? To best answer this, we have to start by looking at our galaxy, the Milky Way. In 1930, the American astronomer Robert J. Trumpler

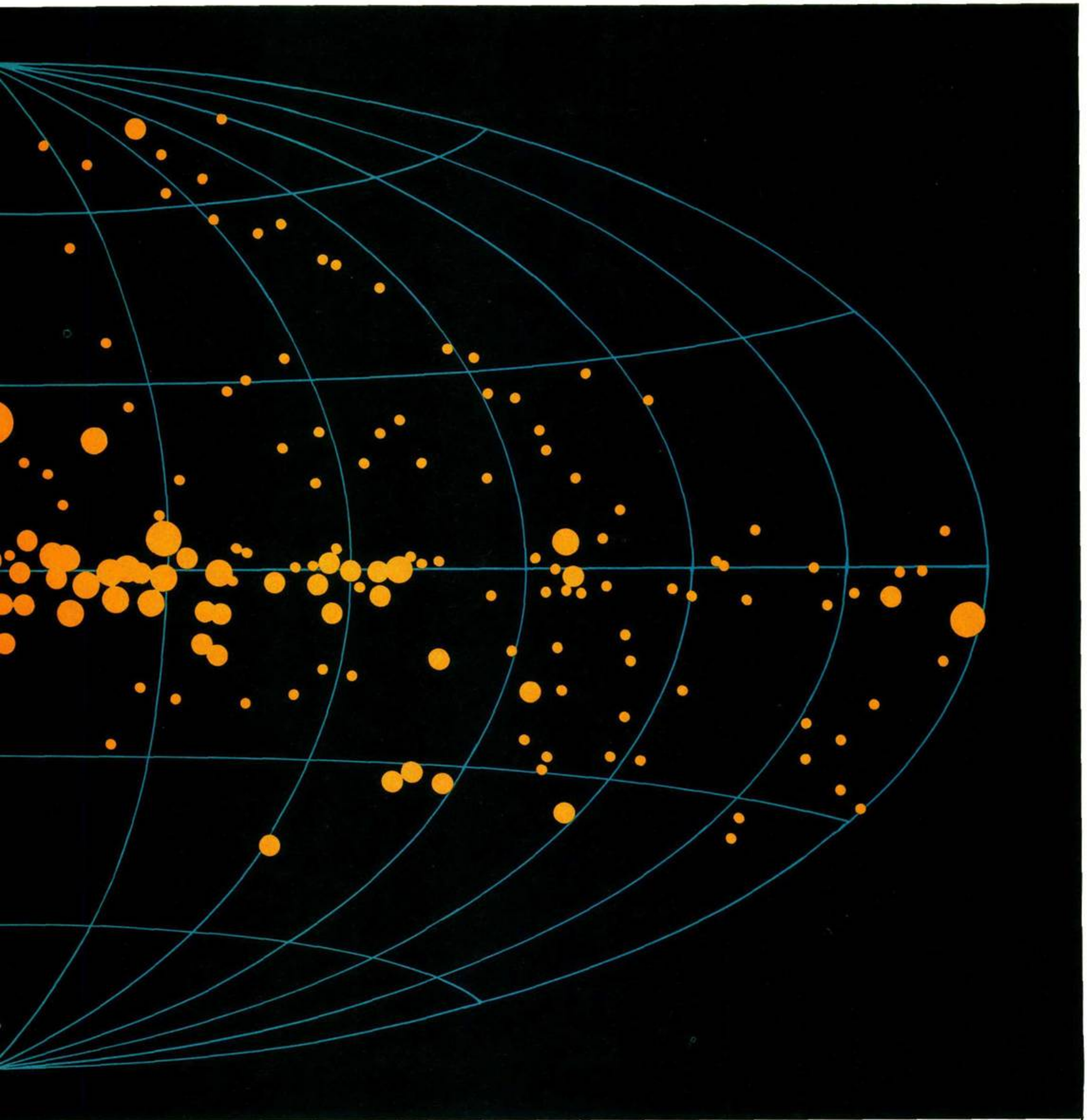


Based on a survey made by the Einstein Observatory, this map shows the entire x-ray sky. Virtually all the points on the plot have been identified as specific x-ray sources. Astronomers believe they understand these discrete sources, but the x-ray background glow is far more perplexing and may not be understood for years. Einstein sky map courtesy NASA.

discovered a thin gas — the interstellar medium — dispersed throughout the Galaxy. Studies have found, however, that high-energy x-rays are not emitted from this interstellar medium. The medium emits some very low-energy x-rays, but it does not account for a general background glow.

Studies have also shown that the x-ray background emission appears to come from the area of space between the galaxies. Is there an intergalactic medium giving off this energy? We don't have direct evidence of an intergalactic medium, but it does seem to be a likely possibility if we consider how galaxies probably formed. Although stars within galaxies formed from the interstellar medium, they did not use up all the available material; a small residue was left behind. Astronomers believe that galaxies aggregated in the same way from an intergalactic medium. If there was leftover material inside galaxies, it seems there would also be some between galaxies.

How hot would this medium have to be to generate the observed amount of x-rays? Calculations show that the plasma would have to be about 500 million degrees! Our real problem, then, is the temperature. Where would the energy to heat an

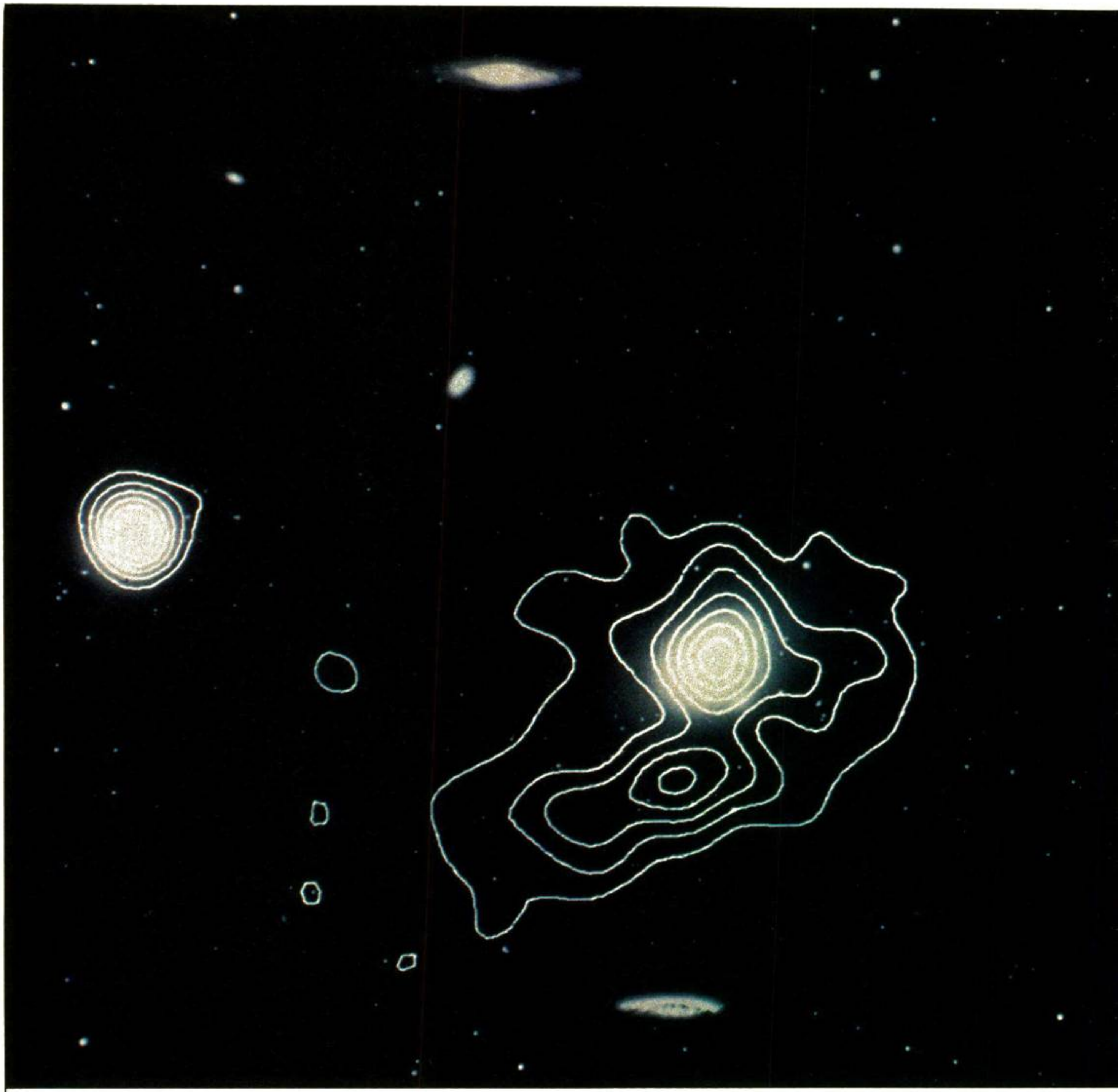


intergalactic medium to such a high temperature come from? And even if it could get so hot, why hasn't it cooled off? Astronomers don't have answers to these questions.

There is, however, some evidence that x-rays are emitted by a hot intergalactic gas. This finding came from the first of three High Energy Astronomical Observatory (HEAO) satellites launched in the late 1970s. One of the experiments obtained a spectrum of the x-ray background that closely matched the spectrum produced by a hot gas.

Additional support for the hot gas theory has recently been found in the strong x-ray emissions coming from clusters of galaxies. These x-rays aren't coming from the stars within the galaxies but from a gas that permeates the cluster. This gas, or hot plasma, is distributed throughout the clusters and appears to surround them. Some astronomers have raised the question: If there is hot plasma in clusters of galaxies, could there also be a plasma spread throughout the universe?

Soon after the discovery of hot plasma gas in clusters of galaxies, astronomers convinced themselves that the x-ray background must be caused by a universally distributed hot plasma. If this is true, though, it has major implications relating to our theories on the expansion of the universe. If the universe contains enough matter, it will eventually stop expanding and collapse; if there is insufficient matter to do this, the universe will expand forever. The amount of matter we see in galaxies is far short of the amount needed to make a closed universe, but there is probably a lot of matter out there that we cannot see directly. The amount lacking is usually referred to as the "missing mass." (See



The Virgo cluster is a prime example of a large group of galaxies that emits significant x-ray radiation. In visible light (left), these galaxies appear merely as fuzzy collections of stars. When viewed with the Einstein Observatory, however, they are seen to be actively emitting x-rays. The x-ray radiation is shown by overlaid contours of equal intensities. NASA photo.

"Mystery of the Missing Mass," November 1984 issue.)

Here's where the hot plasma comes in. If it exists, it would make a sizable contribution to the problem of the missing mass. In fact, astronomers have calculated how much mass the plasma would contribute by determining how many atoms per unit volume are required to give the observed x-ray intensity. The results of these calculations are stunning: The mass of the intergalactic medium is about equal to that of the missing mass. If hot plasma between galaxies exists, this means the universe

is closed and will not expand endlessly.

The idea that the x-ray emission comes from a hot plasma that is spread throughout the universe, therefore, kills two birds with one stone. It explains the x-ray background and it accounts for the universe's missing mass. Unfortunately, the idea has serious problems. The question of where the energy to heat the gas to 500 million degrees comes from is one problem. Even if this hot intergalactic gas did exist, it would heat the gas in and around clusters of galaxies to the point where it would escape from the cluster. However, many clusters have been found to contain gas.

If the x-ray background does not come from an intergalactic gas cloud, where does it come from? Are there other explanations? Perhaps. When the second HEAO satellite — the Einstein Observatory — was launched in 1979, it carried a detector one thousand times more sensitive than earlier models. Within a short time, the satellite discovered numerous x-ray sources, many of which were quasars. Although not well understood, we do know that quasars are highly-energetic x-ray emitting objects, most of which lie at distances far beyond ordinary galaxies. They are receding at appreciable fractions of the speed of light. Is the x-ray background somehow associated with these distant objects?

Since there are a large number of quasars, they seem like good candidates for contributing to the x-ray background. Is there any way to verify this? Theoretically, an astronomer could test this out by taking a long-exposure photograph with x-ray sensitive film of a relatively blank section of sky where there are no known x-ray sources. If the x-rays come from a gas, no new sources would show; on the other hand, if the x-rays come from discrete sources such as quasars, they would show up as bright spots on the film.

Astronomers actually performed this experiment and they did discover many new x-ray sources. There seemed to be no doubt: The x-rays were coming from individual sources, most likely quasars or perhaps a few active galaxies. However, when the spectra of a number of quasars and active galaxies were compared to the x-ray background, they didn't match! Confounded by this complex situation, astronomers realized they needed much more data before unscrambling the mysterious x-ray background.

What are we to make of all this?

Bruce Margon of the University of Washington, Gary Chanon of Columbia University, and Ronald Downes of the University of California at Los Angeles have carefully studied the sources discovered on these long exposures. Their goal is to discover what fraction of these sources are contributing to the x-ray background. There are several problems with this experiment. For one thing, it's difficult to determine how many quasars lie across any given region of sky. More perplexing is the evolutionary effect: looking into space means looking backward in time, so we're seeing quasars at many different ages. This introduces a calibration problem, since the spectral characteristics of different quasars may change with age.

Another study of the contribution of active sources to the x-ray background was conducted by Martin Elvis of Harvard, Andrzej Soltan of the Copernicus Astronomical Center of Warsaw, Poland, and William Keel of Kitt Peak National Observatory. Rather than quasars, their work focused on low-luminosity active galaxies. According to their findings, these objects contribute about 16 percent of the x-ray background.

Regardless of whether the source is quasars or hot gas, there's another problem that's not easy to get around. The x-rays we've been discussing have relatively high energy levels. To complicate matters, there are probably low-energy, or "soft," x-rays also coming from these sources. Unfortunately, these are invisible to us because the Milky Way itself gives off low-energy x-rays. This soft x-ray background was discovered and observed by the HEAO satellites. Unlike the radiation from deep space, it is not uniform around us but shows a patchy distribution with occasional "hot spots." Most of this soft radiation probably originates in hot regions of plasma in intergalactic space.

Because of the low-energy contribution from our Milky Way galaxy, studying the overall low-energy x-ray background is complicated. Some of the intergalactic gas may be at a relatively low temperature; if so, we can't detect it. This low-temperature might also contribute significantly to the missing mass.

What we know is that an x-ray background does exist. It may originate from a tremendously hot intergalactic gas cloud or from quasars and other distant energetic galaxies. Perhaps it comes from both. There's still a great amount to learn about x-ray astronomy. Hopefully, pursuing this field will teach us not only about x-ray radiation but also about the early universe and its ultimate fate.

Barry Parker, an astrophysicist at Idaho State University, recently authored the textbook Concepts of the Cosmos. *His article "Celestial Pinwheels: The Spiral Galaxies" was featured in the May 1985 issue of ASTRONOMY.*

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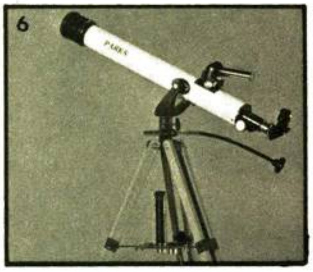
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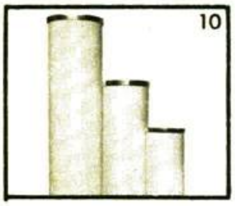
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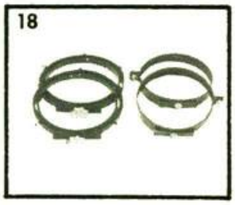
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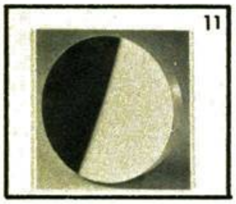
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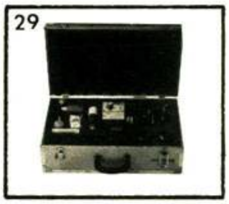
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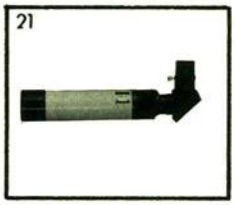
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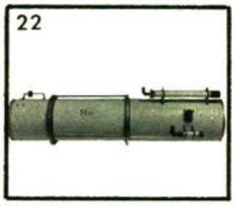
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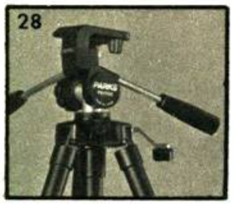
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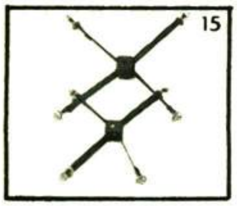
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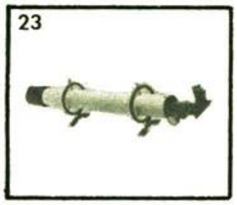
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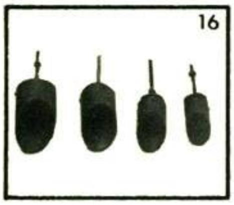
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Fiberglass Tubes & End Rings (10)

For 4½" Mirror	
5" I.D. x 48"	39.00
For 6" Mirror	
7" I.D. x 31" to 52"	52.00
7" I.D. x 53" to 60"	56.00
Anodized Alum. End Rings per pair	20.00
For 8" Mirror	
9⅜" I.D. x 24" to 37"	56.00
9⅜" I.D. x 38" to 55"	68.00
9⅜" I.D. x 56" to 60"	72.00
9⅜" I.D. x 61" to 75"	80.00
Anodized Alum. End Rings per pair	25.00

(Cont'd)

For 10" Mirror	
11⅞" I.D. x 40" to 48"	99.00
11⅞" I.D. x 49" to 62"	116.00
11⅞" I.D. x 63" to 72"	132.00
Anodized Alum. End Rings per pair	34.00
For 12½" or 14¼" Mirror	
15⅞" I.D. x 48" to 59"	148.00
15⅞" I.D. x 60" to 69"	160.00
15⅞" I.D. x 70" to 79"	170.00
15⅞" I.D. x 80" to 100"	190.00
Anodized Alum. End Rings per pair	40.00
For 16" Mirror	
18" I.D. x 48" to 60"	160.00
18" I.D. x 61" to 90"	240.00
18" I.D. x 91" to 120"	280.00

Parabolic Primary Mirrors (11)

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8" f/7 Mirror	219.00
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10" f/6 Mirror	395.00
10" f/7 Mirror	395.00
12½" f/5 Mirror	699.00
12½" f/6 Mirror	699.00

Elliptical Secondary Mirrors (12)

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1.55" Elliptical Mirror	29.00
1.83" Elliptical Mirror	35.00
2.14" Elliptical Mirror	41.00
2.60" Elliptical Mirror	50.00
3.10" Elliptical Mirror	75.00

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Spider 15⅞" I.D. Tube	17.00
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3.10" Diagonal Holder	25.00

Setting Circles (16) (17)

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6" Engraved Alum. Setting Circles 1½" Bore	49.00

Mounting Rings (18)

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Clamp Rings 11⅞" I.D. Tube	70.00
Clamp Rings 15⅞" I.D. Tube	80.00
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10 lb., 1½" Bore	37.00
25 lb., 1½" Bore	69.00
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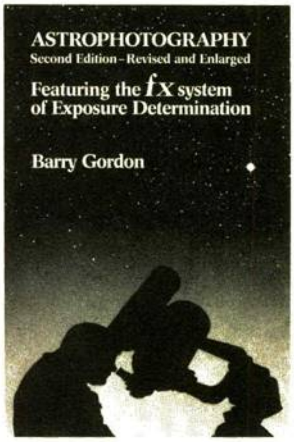
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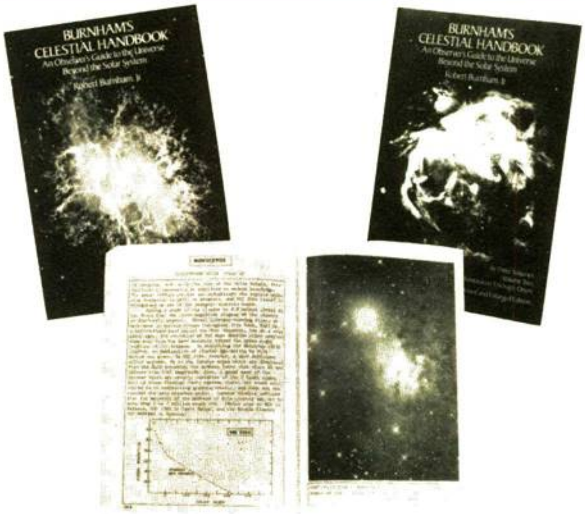
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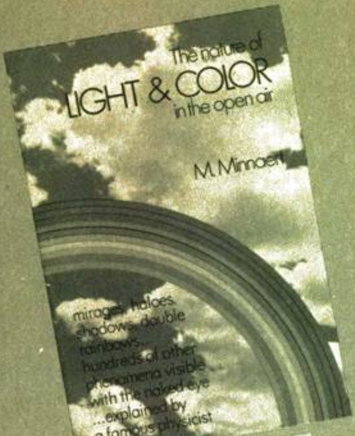
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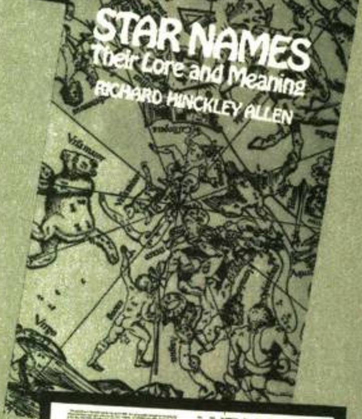
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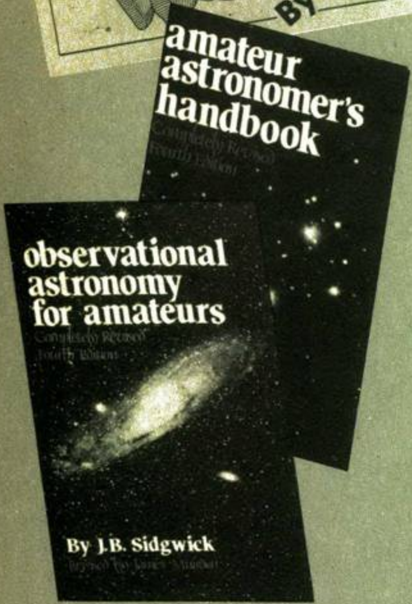
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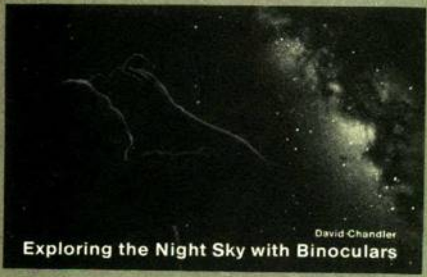
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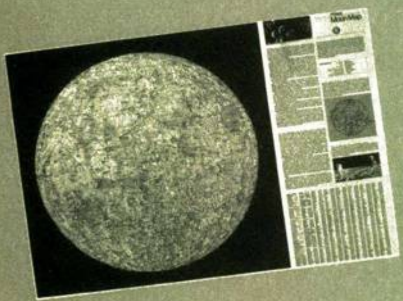

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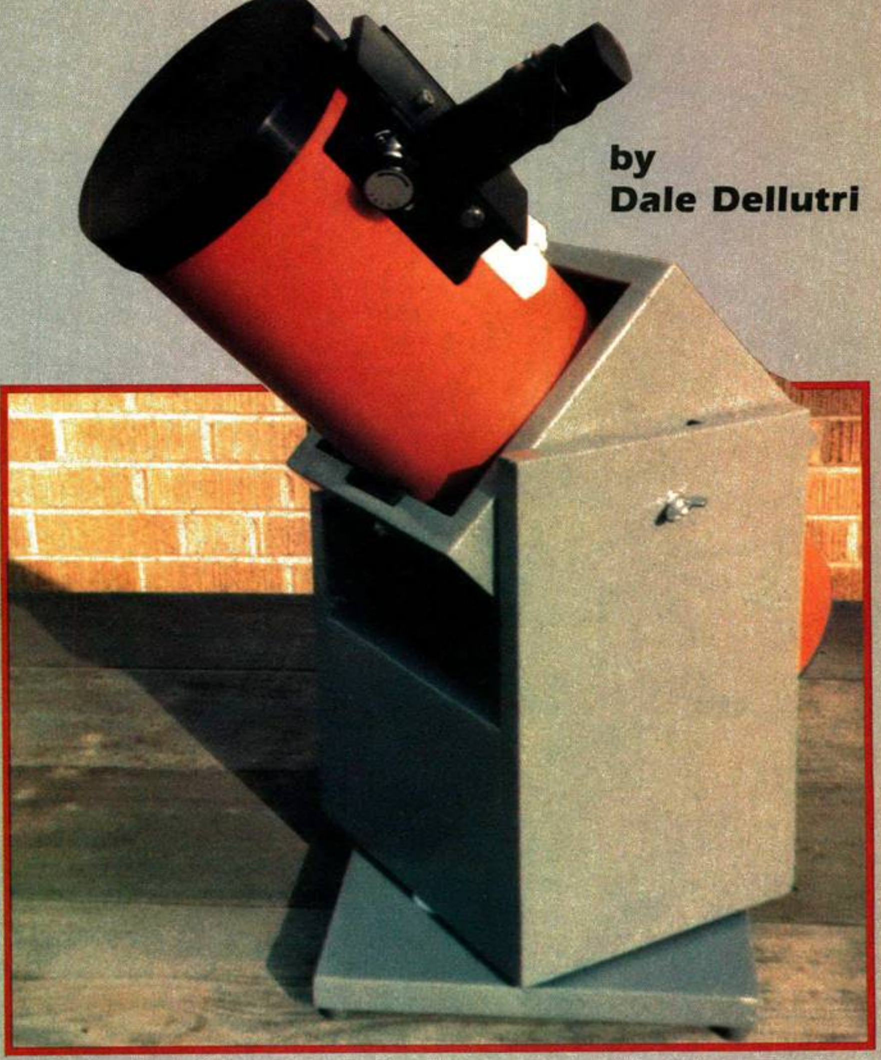
A Compact Mount for a Compact Scope

by Dale Dellutri



I had a little problem.

A while back, I bought the basic model Comet Catcher because I liked its compact size and bright views of deep-sky objects. I've been generally pleased with the telescope, but the photographic tripod I bought to use as a mounting soon became a major source of frustration.

The tripod has no pan head, so altitude adjustments are difficult. All too often I would find an object but be unable to tighten the head without losing my target — and, of course, any kind of tracking was impossible. When the frustrations of using the tripod finally outweighed the pleasure I got from using the telescope, I decided to build a proper mounting.

I had three design goals in mind. First, the mount should be easy to use for visual observing. I didn't want to bother with setting circles or polar alignment, and I had no desire to do astrophotography. This pointed me toward a Dobsonian design.

Second, I wanted a mounting small enough to pack inside the telescope's own carrying case along with the scope and its accessories. I wanted a single neat package when I set out to observe.

Third, the mounting had to be easy to build. I've done enough woodworking to know how difficult it is to get straight cuts actually straight and square corners actually square.

The final design (see opposite page) satisfies all three criteria quite well. The mounting contains nothing exotic in the way of materials or construction. The material I used was ¾'' plywood, which is glued and screwed together. The telescope tube slides mirror first into the rocker box, which is suspended in the spin box by two Teflon bearings, each ⅞'' long and cut from a 2''-diameter rod. The spin box sits on a baseboard separated by a similar Teflon bearing. To keep it from tipping, three small Teflon bars are imbedded in slots cut into the base. The trickiest part of the whole thing was cutting the slots to accept the bearings and the telescope's tripod-adapter plate. These are ⅜'' deep and the fit has to be snug but not tight. As the old adage has it: measure three times, cut once!

Since I didn't know how much pressure would be needed on the Teflon bearings to get smooth movement and no backlash, I drilled out all the bearings to accept bolts. In the field, I could then tighten up the wing-nuts to get the final pressure just right.

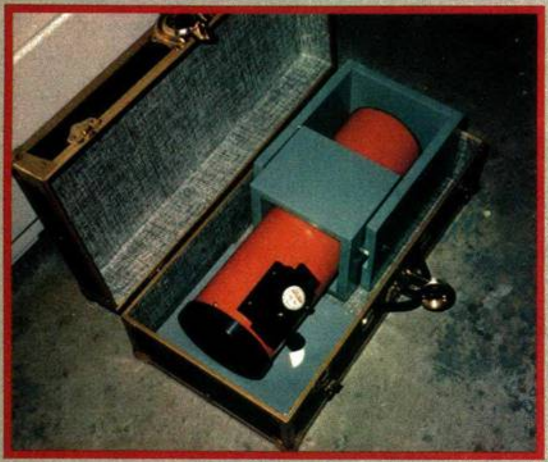
All bolts are ¼-20, the same as the bolt on any tripod. The three that pass through the bearings are 1¾'' long; a 1'' bolt secures the telescope itself to the rocker box. I knew that heavy eyepieces or other accessories would require different balancing points for the scope, so I drilled three holes in the bottom of the rocker box to allow for adjustments. All bolt heads are countersunk; standard ¼-20 nuts (you could also use ¼-20 tee-nuts) are glued into small hexagonal recesses cut with a chisel. I sealed and painted the wood and put four small plastic feet on the bottom of the baseboard. Total construction time: three evenings.

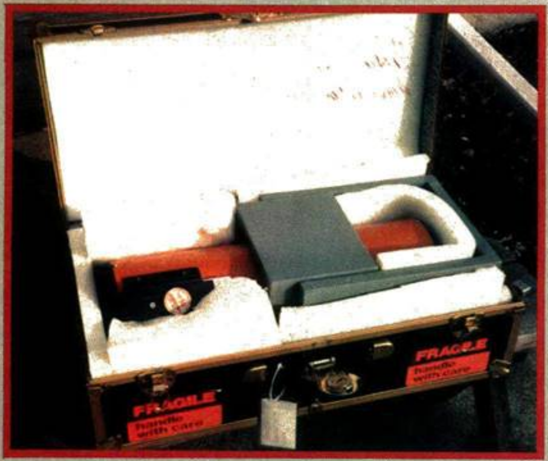
The complete mount and telescope stands less than two feet high. I use the little mounting by itself whenever I have a sturdy, waist-high support available, such as a picnic table or car hood. But if I'm observing way off in the wilderness, I remove the baseboard and bottom bearing and attach the spin box atop the photo tripod. The tripod then provides the azimuth adjustment.

The results have been fantastic. On my first observing session with the new mount, I saw and tracked more objects than I had in all the previous sessions using the tripod! The mount is steady enough and adjustments are smooth enough to let me use a 4 millimeter eyepiece (125x) for planetary work.

The mount has definitely met all my design goals. And I now have a complete telescope system to take on my Halley expedition next month.

To make a compact mounting for a compact telescope use the plans below to lay out the pieces on a sheet of 3/4″ plywood. The assembly view (right) shows how the parts go together. Although the specifications fit a Comet Catcher, the design will work with almost any small, stubby telescope if you adjust the dimensions appropriately.

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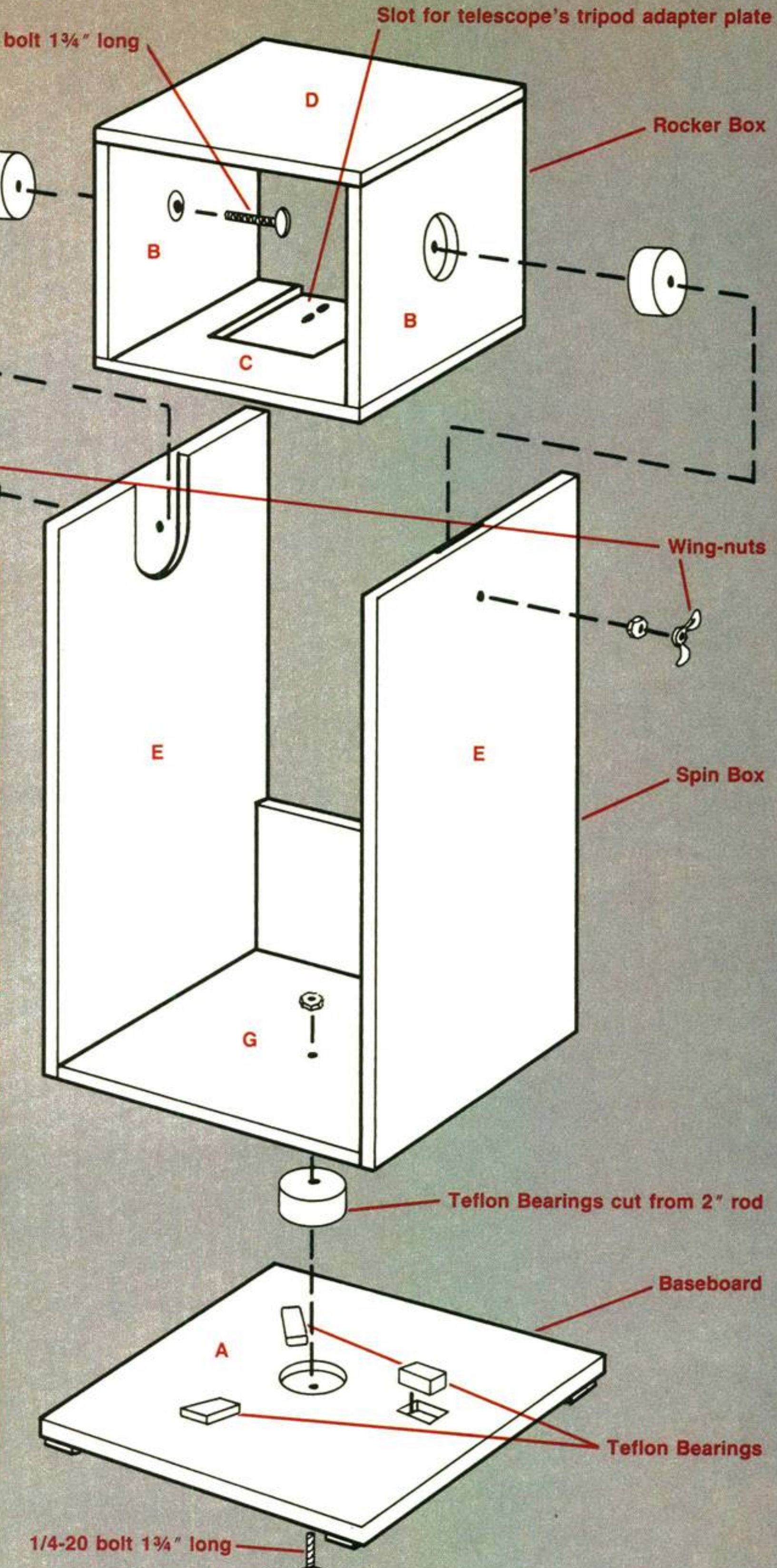
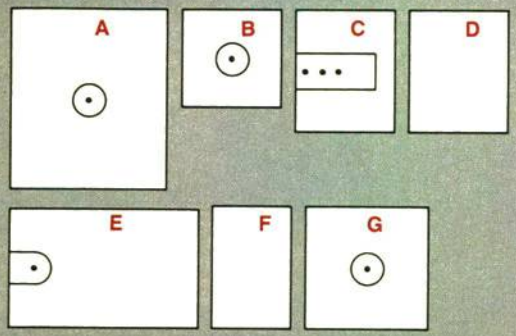
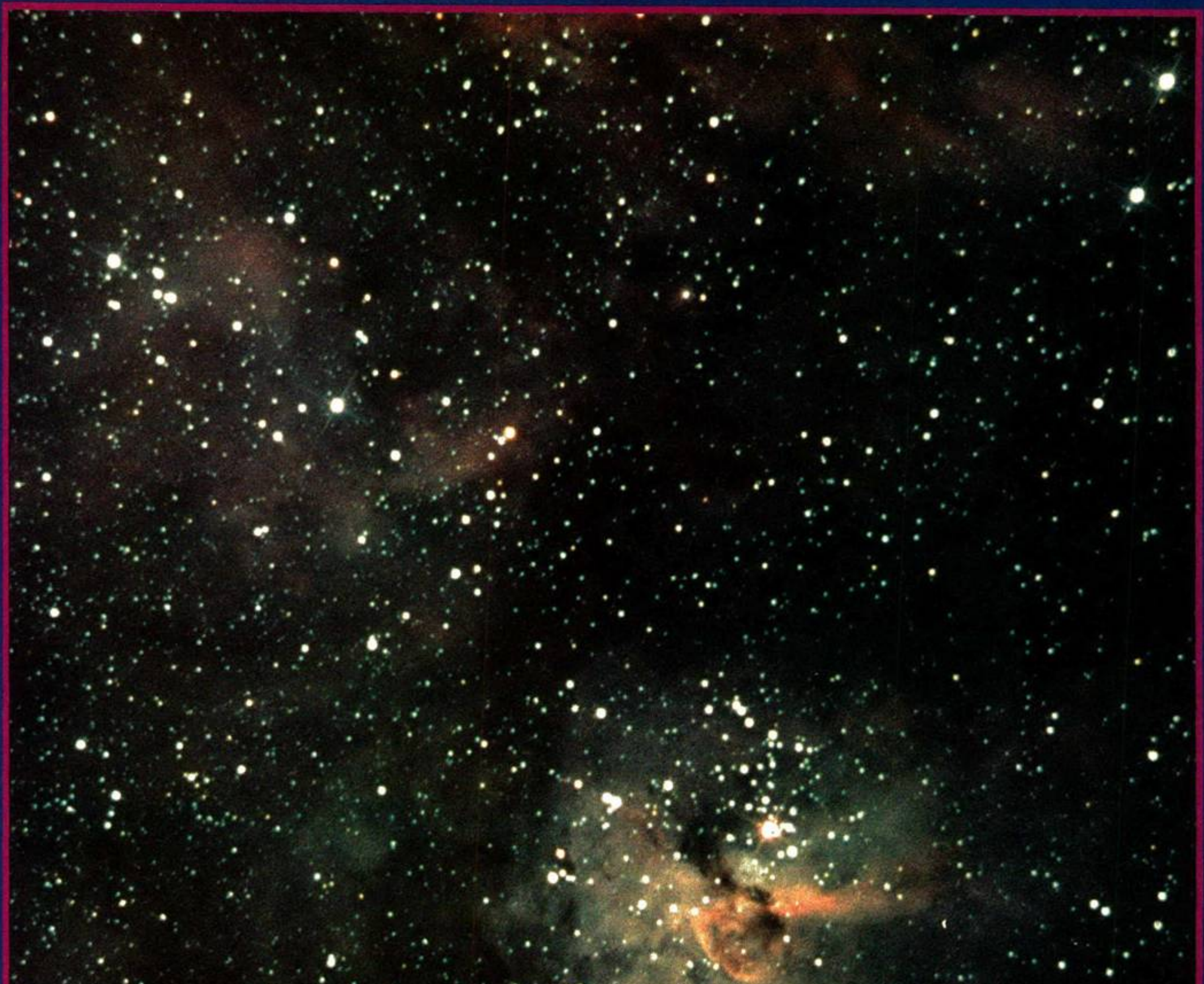

1/4-20 bolt 1¾″ long
Slot for telescope's tripod adapter plate
D
Rocker Box
B
B
C
Wing-nuts
E
E
Spin Box
G
Teflon Bearings cut from 2″ rod
Baseboard
A
Teflon Bearings
1/4-20 bolt 1¾″ long



Part A: 11¼″ by 9½″; bearing slot is 2″ in diameter and ⅜″ deep. (Dimensions of the support bearing slots depend on the Teflon pieces available.)
Part B (make 2): 6″ square with a 2″ diameter slot ⅜″ deep.
Part C: 6″ by 7½″; slot is 5″ by 2¼″ and ⅜″ deep.
Part D: 6″ by 7½″.
Part E (make 2): 7½″ by 11½″. Bearing slot is ⅜″ deep and 2⅛″ wide; its rounded bottom is 2⅛″ in diameter and is centered 1½″ away from the edge.
Part F: 4¾″ by 7¾″.
Part G: 7½″ by 7¾″; bearing slot is ⅜″ deep with a 2⅛″ diameter.

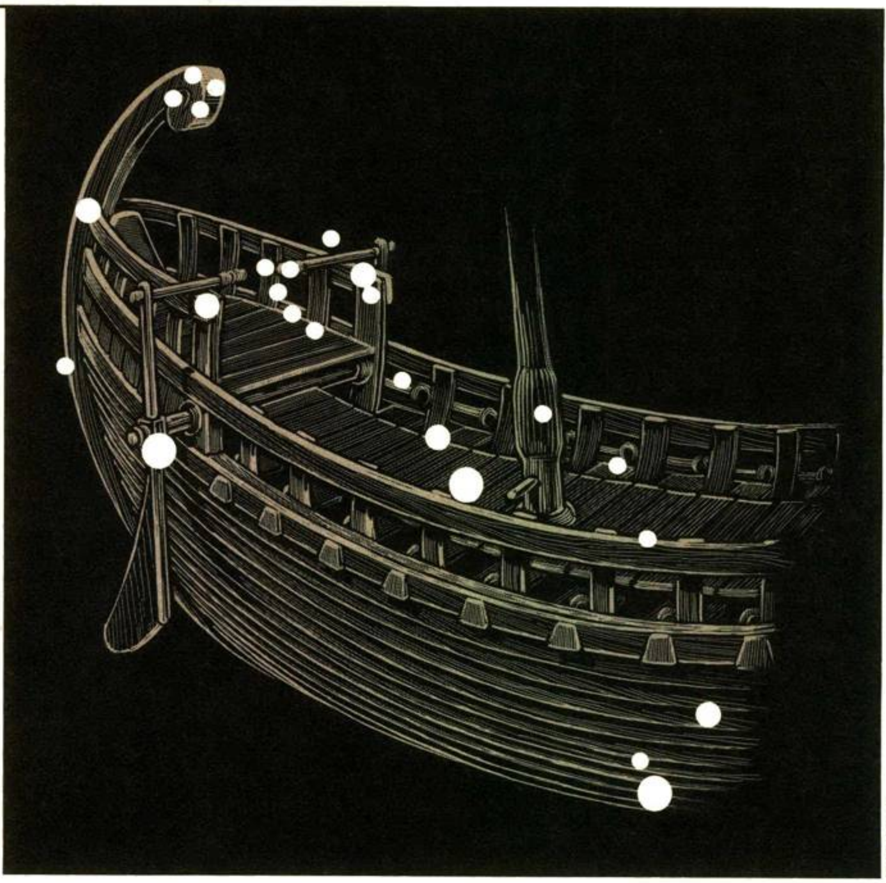


The bright, exceptionally detailed emission nebula NGC-3372 surrounds the variable star Eta Carinae. This nebula is visible as a large fuzzy patch without optical aid. Photo by Jim Barclay.

Carina

Car

Carinae



Keith Ward

Still stabilizing the old ship Argo Navis, **Carina** the Keel encompasses one of the richest areas of the southern Milky Way. Although largely invisible to most Northern Hemisphere viewers, Carina holds such a collection of deep-sky goodies that it alone warrants an observing trip to the Southern Hemisphere. Found in Carina are the huge, impressive clusters NGC-2516 and NGC-3532, the famed Eta Carinae nebula and the sky's second brightest star, Canopus.

Dazzling and unmistakable to Southern Hemisphere observers is **Canopus** (Alpha [α] Carinae), the brightest star in the sky after Sirius. Canopus lies approximately 35° south of Sirius, making it visible during the winter from latitudes as far north as the southern United States. Sirius is bright because it lies just 2.7 parsecs away, but Canopus is nearly as bright despite its distance of 60 parsecs. It shines at magnitude −.7 and is a type F0 supergiant — an intrinsically brilliant star some 30 times larger and 1,400 times more luminous than the Sun.

Another interesting object in Carina is **Eta** (η) **Carinae**, an unusual nebular variable star 500 parsecs distant with a bizarre observational history. In 1677, Edmond Halley classified Eta Car as a 4th-magnitude star. During the following century it varied erratically in brightness: in 1730 it shone at 2nd magnitude, in 1782 it was near 4th magnitude, and by 1820 it had repeated this cycle again. Eta Car then started brightening quickly, reaching 2nd magnitude in 1822 and 1st magnitude by 1827. In 1843 it was as bright as Canopus, but by 1868 it had faded out of naked-eye visibility. In 1900 the star was at 8th magnitude and has since hovered quietly around 6th or 7th.

What is going on with this star? It seems to be a type of recurring nova with a spectrum that changes dramatically during rises and subsequent falls. The unique emission features in the star's spectrum that indicate a shell of gas surrounding the star as well as ionized iron and other metals remain puzzling for astronomers. Similar features are observed in novae but Eta Carinae seems to hold a unique position, temporarily at least, among the stars in our galaxy.

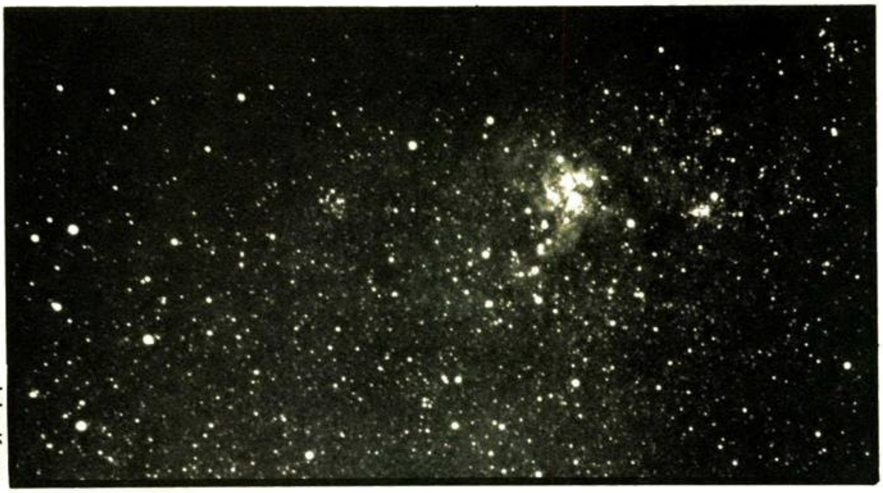
In a telescope, Eta Carinae itself isn't a terrific sight. However, surrounding the star is the bright emission nebula **NGC-3372** — sometimes called the Eta Carinae or Keyhole nebula — one of the largest and brightest deep-sky objects in the entire sky. The Eta Carinae nebula consists of four large sections of nebulosity so bright that each can be glimpsed with the naked eye. The sections are divided by a wide, opaque dust lane that provides the Keyhole nebula with its nickname. The entire object is far brighter than M-42, Orion's Great nebula, and covers a whopping 120′ of sky. It is visible as a huge, glowing, misty patch even on average nights. Binoculars trained on the nebula show bright triangle-shaped patches of nebulosity well separated by the dust lane. Since the nebula lies in the thick of the southern Milky Way, the field is strewn with hundreds of stars that are arranged in lines and pairs. A small telescope reveals an amazing amount of detail within the Eta Carinae nebula, including wisps of very faint nebulosity on the outskirts of the object and intricate jets of nebulosity projected against the dark lane.

Carina contains two other notable nebulae for small telescopes. **NGC-3581** is a small, fan-shaped nebulosity that is visible as a wisp of milky light. If you spot this nebula, look carefully around the field of view. Several detached pieces having the separate NGC designations of 3579, 3582, 3584, and 3586 lie within several arc-minutes of NGC-3581. **NGC-2867** is a bright planetary nebula that appears as an out-of-focus star in small scopes at high power. With a photographic magnitude of 9.7, it's easy to spot providing you employ medium to high power. This nebula is a mere 11″ across and has a slightly blue-green color, which may help you pick it out from the myriad field stars. The central star shines at 14th magnitude and is exceedingly difficult to spot visually.

Besides nebulae and unusual stars, Carina is loaded with bright star clusters. One of the best is **NGC-2516**, a gathering of some 80 stars of magnitude 7 and fainter over an area the diameter of the Full Moon. With a total magnitude of 3.8, NGC-2516 is quite easily visible to the naked eye and appears as a large hazy patch of unresolved light. Binoculars resolve the cluster into its constituent stars, creating a view of several dozen bright white and bluish white stars scattered across the entire field.

Also bright and large is **NGC-3114**, a cluster containing several dozen stars in

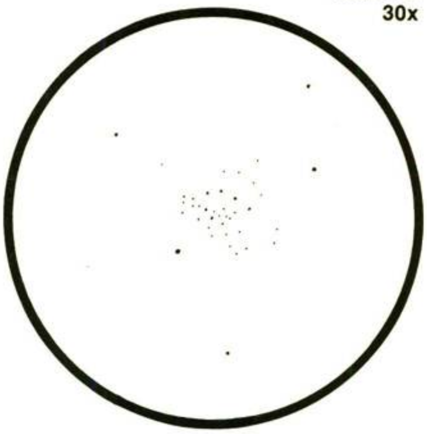
For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.


John Kerns

NGC-3372 and environs

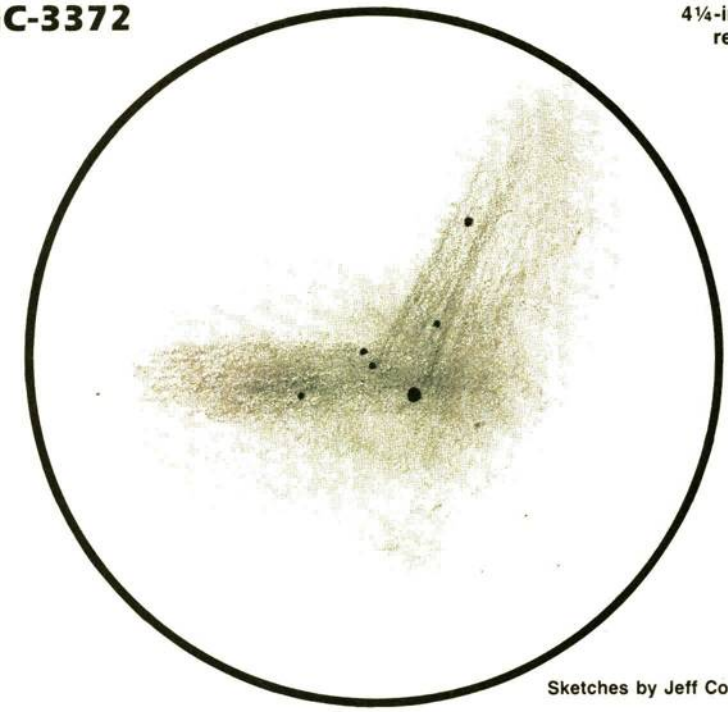
NGC-3293

4¼-inch f/8
reflector
30x



NGC-3372

4¼-inch f/8
reflector
30x



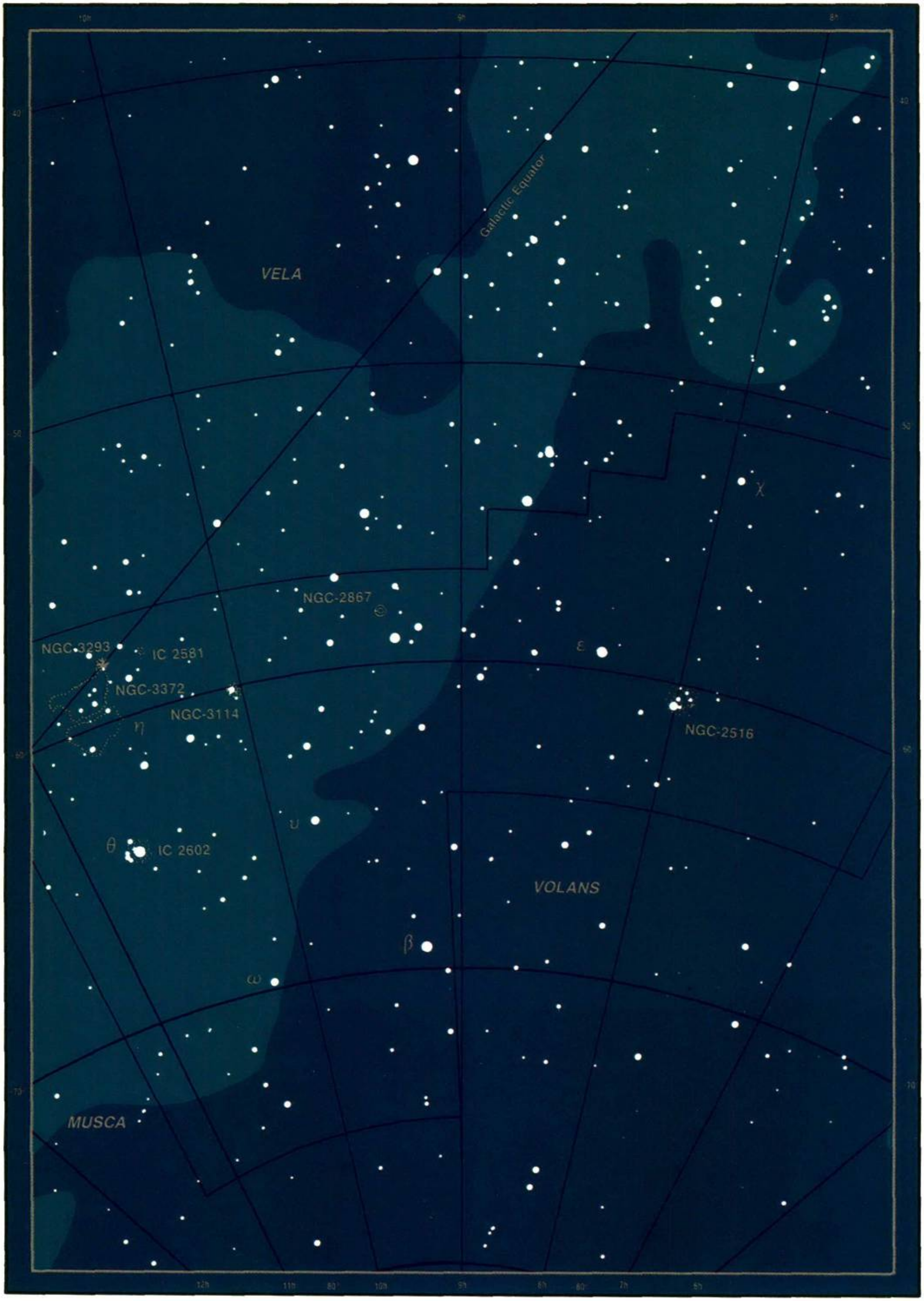
Sketches by Jeff Corder

a 35′ diameter. The group's total magnitude is 4.2 with its brightest stars shining at 7th magnitude. Compare NGC-3114 with NGC-2516 — which do you enjoy better? Which cluster has the most colorful stars? **NGC-3532** is another very bright cluster. It covers nearly a degree of sky — 55′ — and holds some 150 stars of magnitude 7 and fainter. The group's total magnitude is 3.0, making it an easy naked-eye target even on nights of poor seeing.

Carina holds four other open clusters that are ideal for small telescopes. **NGC-3293** is very small, only 6′ across, but bright; its several dozen stars give it a combined magnitude of 4.7. **IC 2581** is a cluster of 25 stars in an area spanning 8′ across. It contains a single 4th-magnitude star, which contributes greatly to its total brightness. **IC 2602**, also known as the Theta Carinae cluster, contains Theta (θ) Car and 60 other members in an area almost a degree across. Because Theta is a magnitude 2.8 star, this dazzling cluster shines at magnitude 1.9 making it visible without optics and very bright in binoculars. **IC 2714** is not so bright but very rich — it packs 100 stars within a 12′ circle.

Object	M#	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.
Alpha (α)		★	6h 23.9m	−52°42′	−0.7	—
NGC-2516		⊙	7h 58.3m	−60°52′	3.8	30′
NGC-2867		■	9h 21.4m	−58°19′	9.7p	11″
NGC-3114		⊙	10h 02.7m	−60°07′	4.2	35′
IC 2581		⊙	10h 27.4m	−57°38′	4.3	8′
NGC-3293		⊙	10h 35.8m	−58°14′	4.7	6′
IC 2602		⊙	10h 43.2m	−64°24′	1.9	50′
NGC-3372		☐E	10h 43.8m	−59°52′	—	120′x120′
Eta (η)		IV	10h 45.1m	−59°41′	6.21v	irr.
NGC-3532		⊙	11h 06.4m	−58°40′	3.0	55′
NGC-3581		☐E	11h 12.0m	−61°12′	—	—
IC 2714		⊙	11h 17.9m	−62°42′	8.2p	12′

★	*Star*
IV	*Irregular Variable*
⊙	*Open Star Cluster*
■	*Planetary Nebula*
☐E	*Emission Nebula*


10h
9h
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Galactic Equator
VELA
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NGC-2867
NGC-3293
IC 2581
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NGC-3372
NGC-3114
NGC-2516
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IC 2602
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11h
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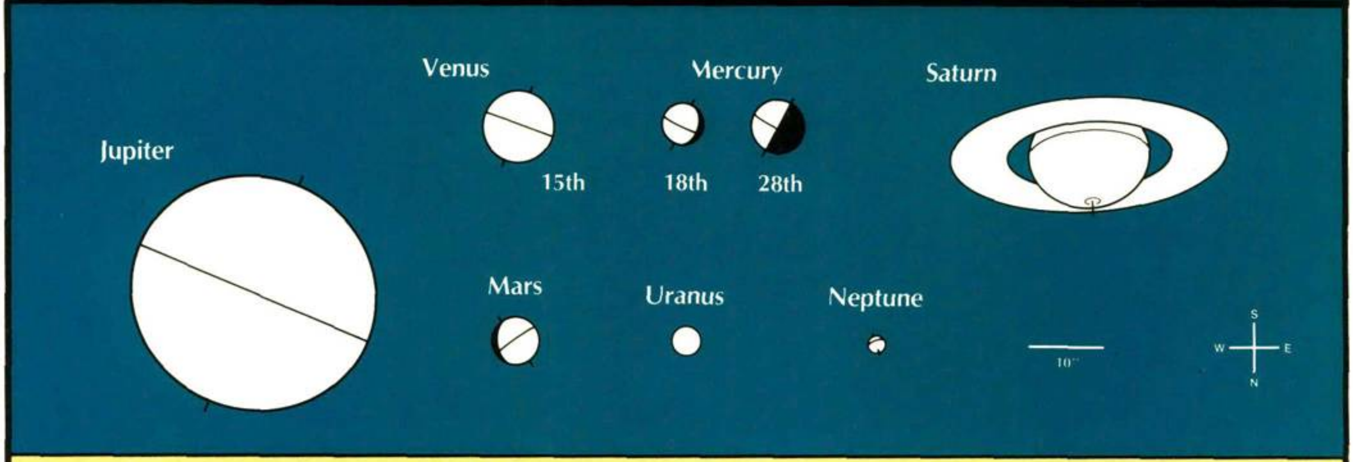
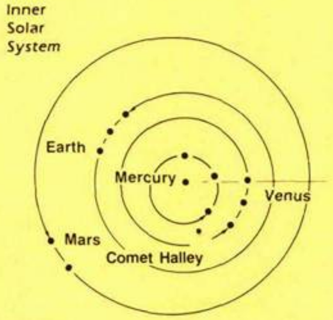
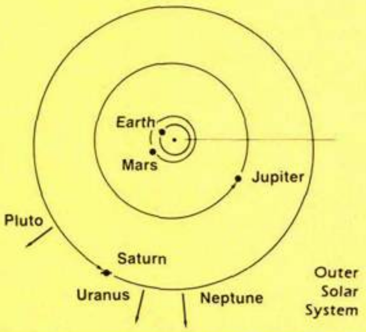
9h
8h
80°
7h
6h

Planetary Data February 1986


Venus
Mercury
Saturn
Jupiter
15th
18th
28th
Mars
Uranus
Neptune
10″
S
W
E
N

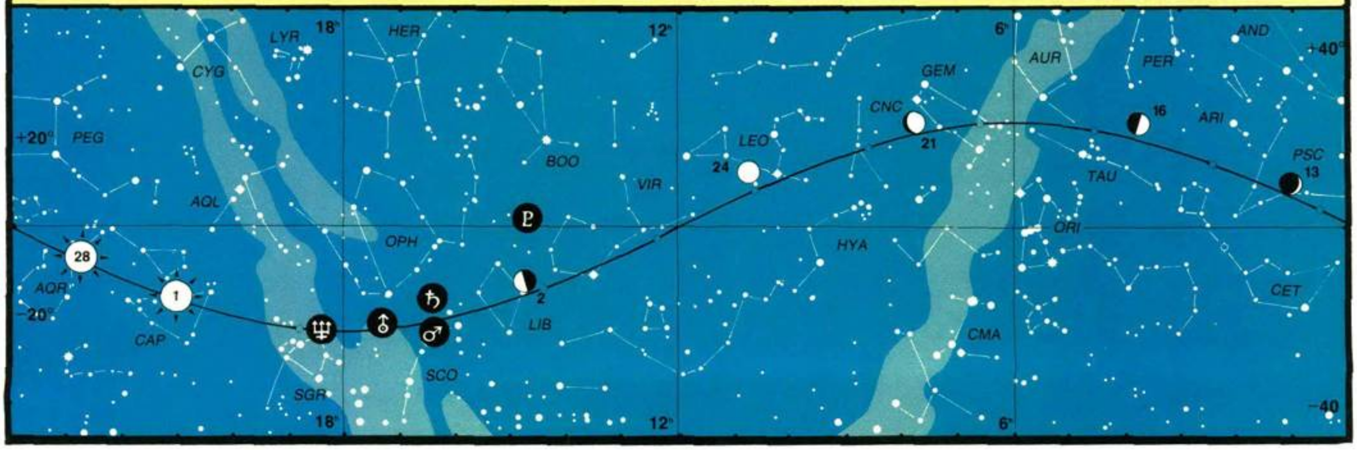
		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Distance (AU) from: Sun	Longitude: Heliocentric	Longitude: Ecliptic	R.A. (2000.0)	Dec.
Sun		1	−26.8	32.5′	—	0.99	—	—	311°49.9′	20h 57.9m	−17°11.5′
		15	−26.8	32.4′	—	0.99	—	—	326°00.8′	21h 53.8m	−12°47.2′
		28	−26.8	32.3′	—	0.99	—	—	339°06.4′	22h 43.5m	− 8°05.3′
Mercury	☿	1	−1.4	4.8″	100%	1.40	0.42	311°44.4′	312°01.9′	21h 00.2m	−19°12.1′
		15	−1.2	5.4″	92%	1.26	0.34	9°47.5′	337°02.8′	22h 36.9m	−10°01.6′
		28	−0.5	7.1″	51%	0.95	0.31	86°19.2′	357°09.4′	23h 48.1m	0°14.8′
Venus	♀	1	−3.9	9.8″	100%	1.71	0.73	318°48.8′	314°59.3′	21h 11.3m	−17°34.1′
		15	−3.9	9.8″	99%	1.70	0.73	340°59.4′	332°32.7′	22h 20.1m	−11°55.3′
		28	−3.9	9.9″	99%	1.68	0.73	1°38.3′	348°48.0′	23h 21.0m	− 5°44.2′
Mars	♂	10	1.0	6.2″	90%	1.52	1.60	207°47.2′	244°44.4′	16h 11.7m	−20°22.6′
		20	0.9	6.6″	90%	1.42	1.59	212°32.0′	250°31.4′	16h 36.1m	−21°25.8′
Jupiter	♃	15	−2.0	32.8″	100%	6.01	5.02	329°10.0′	328°50.6′	22h 05.1m	−12°39.1′
Saturn	♄	15	0.5	16.3″	100%	10.15	9.98	243°17.7′	249°00.7′	16h 30.5m	−19°57.0′
Uranus	⛢	15	5.7	3.6″	100%	19.53	19.13	258°59.9′	254°27.0′	17h 24.5m	−23°15.5′
Neptune	♆	15	8.0	2.2″	100%	30.86	30.25	273°38.9′	271°33.6′	18h 22.9m	−22°16.2′
Pluto	♇	15	13.7	0.1″	100%	29.42	29.73	215°28.3′	212°15.6′	14h 42.3m	1°50.9′


Inner
Solar
System
Earth
Mercury
Venus
Mars
Comet Halley


Earth
Mars
Jupiter
Pluto
Saturn
Uranus
Neptune
Outer
Solar
System

Moon Data

Last Quarter.........February 2 at 4h41m
New Moon.........February 9 at 00h55m
First Quarter.......February 16 at 19h55m
Full Moon.........February 24 at 15h02m
Last Quarter..........March 3 at 12h17m
New Moon..........March 10 at 14h52m
Perigee: Feb. 4 at 16h14m....368,821 km.
Apogee: Feb. 16 at 22h23m...404,257 km.


LYR
18h
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AND
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ARI
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LEO
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BOO
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13
VIR
AQL
♇
OPH
HYA
ORI
28
AQR
1
♄
2
CET
−20°
♆
⛢
♂
LIB
CMA
CAP
SCO
SGR
18h
12h
6h
−40

George Sardis was near Mojave, California when he took this photo of the North America Nebula and the northern part of Cygnus. The reddish line was made by a passing airplane. Sardis used a piggybacked 135mm f/2.8 lens, Ektachrome 400 film, and a 12-minute exposure.

Mercury

Although Mercury is at superior conjunction with the Sun on February 1st (in UT), its motion is so swift that it will pop into view in the evening sky before the month is half gone.

Starting February 13th, look for Mercury very low in the west-southwest during the hour after sunset. Rising a little higher each evening, the planet will attain peak elevation (9°, 45 minutes after sunset) on February 28th, which is also the date of greatest eastern elongation. Mercury will remain a good telescopic target until March 10th when it will sink out of view. This is one of the year's best apparitions of the planet, so don't miss it.

Venus

Having passed through superior conjunction on January 19th, Venus will remain too close to the Sun to be seen until next month.

Mars

As detailed in "Eye on the Sky" this month, Mars will remain near Antares and Saturn; best views of its conjunctions are seen with low magnifications on your telescope.

Over the course of February, Mars will swell slightly in apparent size, from 5.8" across to 7.0". Though still a small object even at medium magnification, the planet's visibility will improve each day. If weather permits, try to view Mars at least once a week. Using a half-inch circle to represent the disk, make a simple sketch of its appearance each time you observe and you will train your eye to pick out more detail in the planet.

Minor Planets

1 Ceres (magnitude 6.7) is at opposition in Leo on February 27th and lies near the star δ Leonis, which it passes about one and a half degrees north of on the 23rd. Its positions:

1st: 11h 27m 11s, 20° 17.7′
10th: 11h 22m 59s, 21° 30.0′
20th: 11h 16m 09s, 22° 49.0′
28th: 11h 09m 34s, 23° 44.7′

Ceres rises around 7:30 p.m. local time on the 15th.

2 Pallas (7.7) is moving northeastward in central Lepus. Its positions:

1st: 5h 39m 17s, −25° 30.6′
10th: 5h 40m 27s, −22° 29.7′
20th: 5h 44m 50s, −18° 56.2′
28th: 5h 50m 31s, −16° 02.7′

Pallas sets around midnight local time on the 15th.

3 Juno (11.4) is moving eastward in southern Ophiuchus. It passes to the south of ζ Ophiuchi on the 5th, missing it by about half a degree. Its positions:

1st: 16h 31m 45s, −11° 14.5′
10th: 16h 40m 27s, −11° 03.4′
20th: 16h 49m 03s, −10° 43.7′
28th: 16h 54m 59s, −10° 22.6′

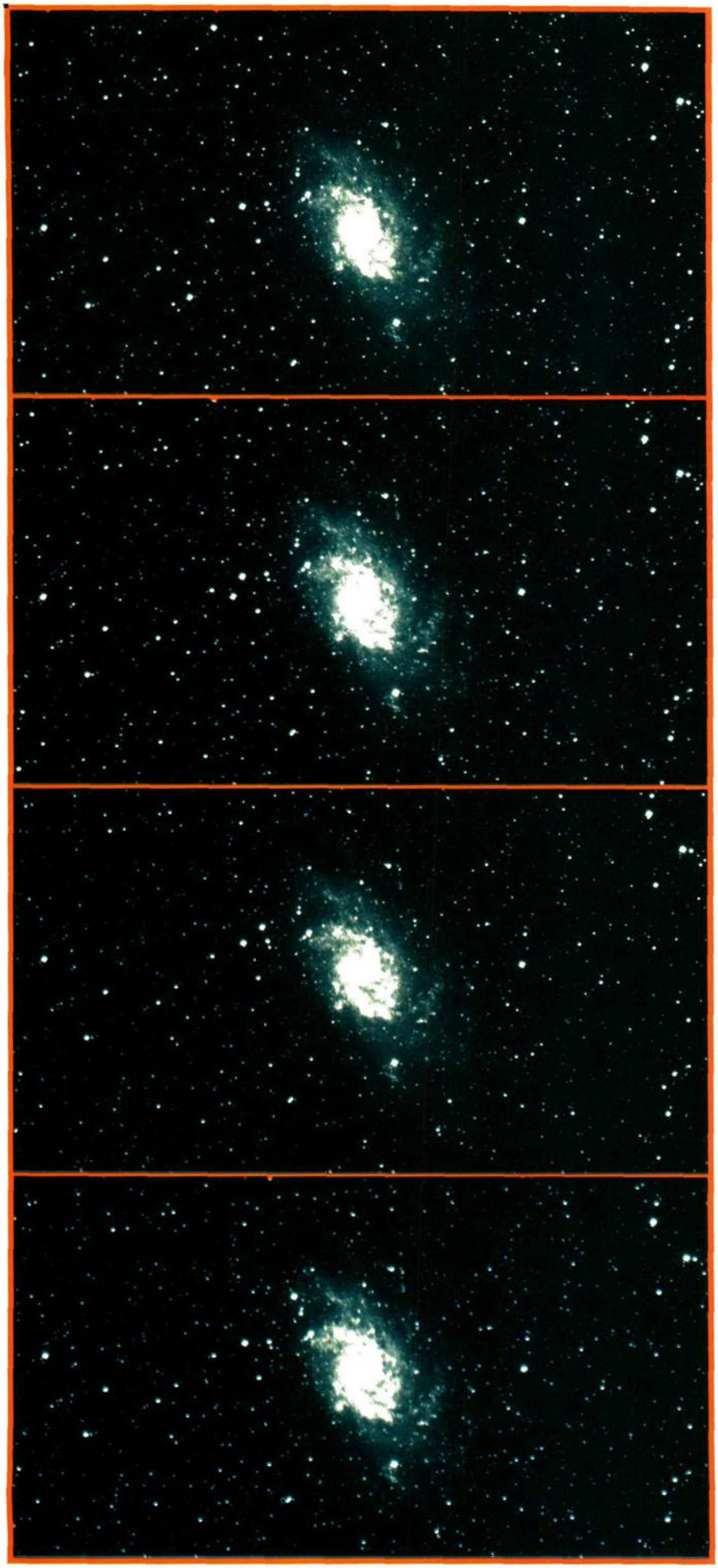
Juno rises around 3 a.m. local time on the 15th.

187 Lamberta (12.3) is moving retrograde on the Leo/Leo Minor border near the star μ Leonis; it is at opposition on February 15th. Its positions:

1st: 10h 11m 32s, 27° 50.2′
10th: 10h 02m 53s, 28° 29.5′
20th: 9h 52m 02s, 28° 57.5′
28th: 9h 43m 35s, 29° 02.7′

Lamberta is visible all night long.

To locate a minor planet, plot its dated positions lightly in pencil on a good star atlas (*Sky Atlas 2000.0*, for example) and sketch a smooth curve linking the points. Then observe the starfield at low magnification and photograph or plot by hand what you see. Check the field a night or two later; the "star" that has moved is it. (All minor planet coordinates are for the epoch 2000.0.)



Right: Marco Milani wins this month's "Best Astro-Photo" award of $100 for his photo of the Crab Nebula, M-1, in Taurus. He used an 8-inch SCT, a telecompressor yielding an f/5 focal ratio, and a 45-minute exposure on Ektachrome 400 film pushed to ISO 800. Left: Last fall, the apparent path of asteroid Eunomia headed toward galaxy M-33 in Triangulum. These photos were taken by Paul Roques on September 14th (top), 16th, 17th, and 18th (bottom). Can you spot the moving dot that's Eunomia? Roques used a 4-inch Schmidt camera and hypered 2415 film.

Jupiter

Jupiter is too close to the Sun to be seen this month.

Saturn

The northern side of Saturn's rings is now tipped 25° toward us; on the 15th, the rings will spread 37″ across.

Though the Voyager craft revealed thousands of individual rings, only three will be visible in your telescope. The outermost is called the A ring; it is 15,200 kilometers across and has one thin gap, called the Encke Division, that is visible in large telescopes on nights of excellent seeing.

The 3,500-kilometer-wide Cassini Division separates the A ring from the 25,300-kilometer-wide B ring. Though the Cassini Division appears dark, the Voyager spacecraft showed that it actually contains a lot of material. The B ring, the brightest and widest of the main rings, is where the Voyager craft observed the now-famous "spokes," which are shadows caused by ring particles lifted slightly by electrostatic effects.

The innermost ring visible in your telescope is the C ring, sometimes called the crepe ring. It extends about 19,000 kilometers inward from the inner edge of the B ring. The C ring looks duskily transparent where it crosses the disk of the planet — perhaps it should be called the "smoke" ring!

Uranus

Located in a southern corner of Ophiuchus between Scorpius and Sagittarius, Uranus will not have much elevation this month — even when it's crossing the meridian. During February, the planet will be around 20° high 45 minutes before sunrise. Scan the region with low magnifications using the finder chart on page 107 of last month's issue. Look for a comparatively bright (magnitude 5.7) blue-green disk 3.6″ across.

Neptune

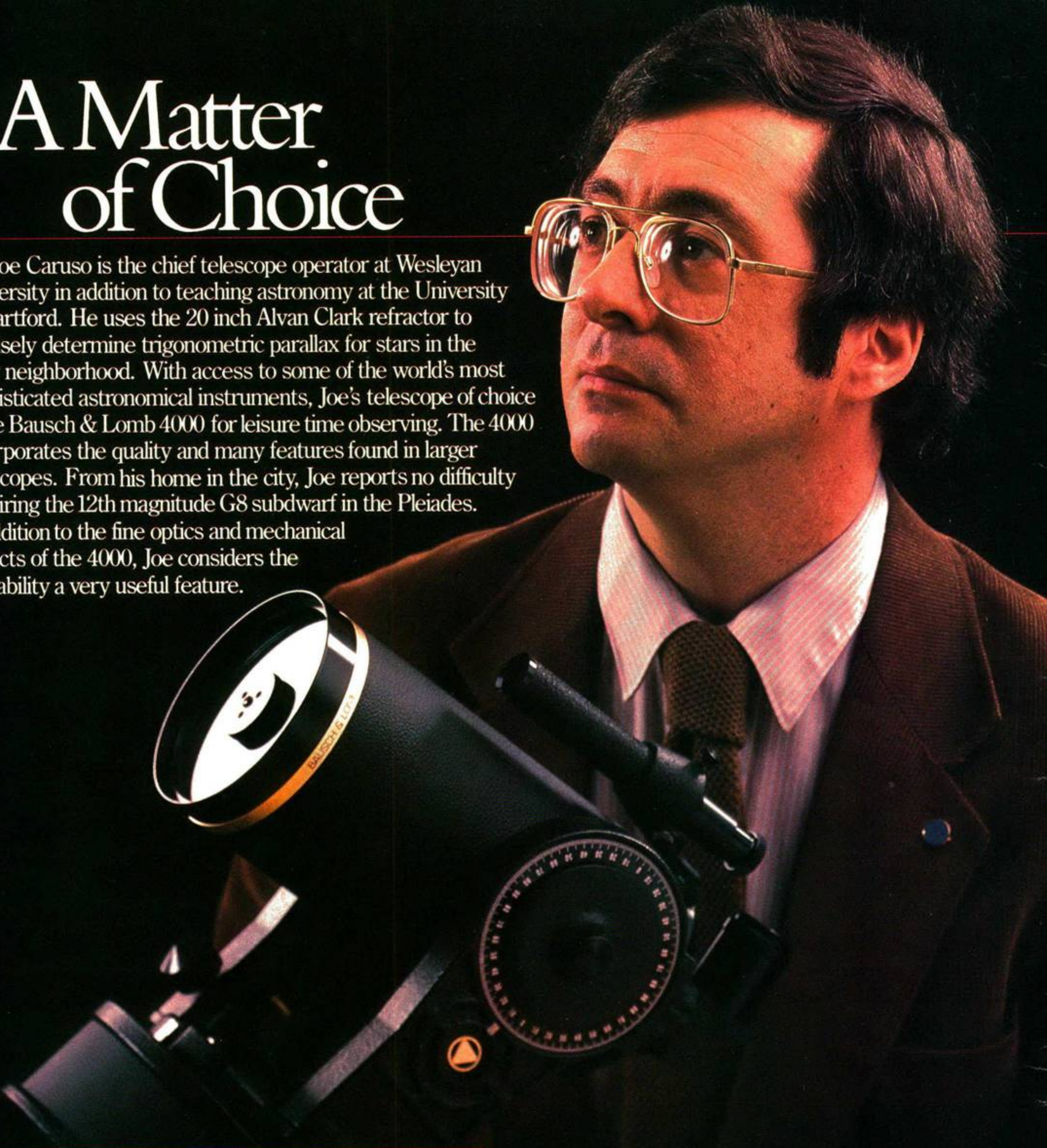
An hour of right ascension to the east of Uranus, Neptune is more difficult to find since it is still quite low as morning twilight begins. Use the January finder chart and look for an 8.0 magnitude greenish disk 2.2″ in diameter.

Comet Halley

Halley is lost in solar glare for most of February. Some sharp-eyed observers, however, will probably recover it very low in the southeastern morning sky by the end of the month. Who'll be the first?

A Matter of Choice

Joe Caruso is the chief telescope operator at Wesleyan University in addition to teaching astronomy at the University of Hartford. He uses the 20 inch Alvan Clark refractor to precisely determine trigonometric parallax for stars in the solar neighborhood. With access to some of the world's most sophisticated astronomical instruments, Joe's telescope of choice is the Bausch & Lomb 4000 for leisure time observing. The 4000 incorporates the quality and many features found in larger telescopes. From his home in the city, Joe reports no difficulty acquiring the 12th magnitude G8 subdwarf in the Pleiades. In addition to the fine optics and mechanical aspects of the 4000, Joe considers the portability a very useful feature.



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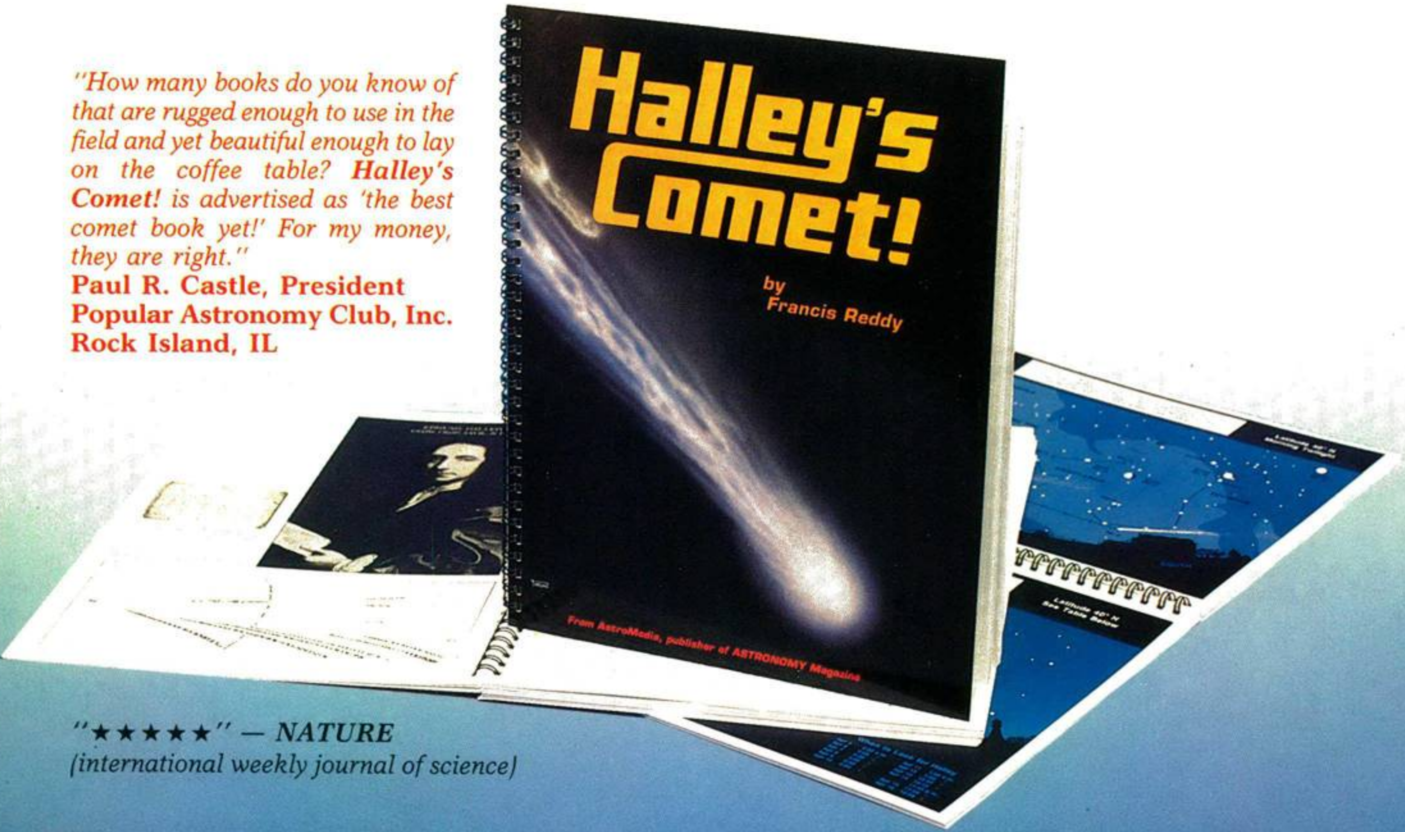

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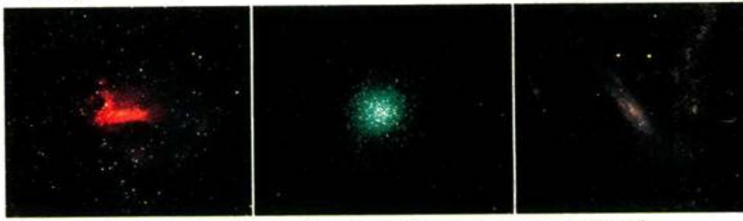

C8 Astrophotographs: M-17, Omega Nebula; M-13, Globular Cluster; NGC-253.

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